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Volume I

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A STUDY OF AEROSPACE GROUND EQUIPMENT REQUIREMENTS FOR LARGE SOLID PROPELLANT ROCKET MOTORS

TECHNICAL DOCUMENTARY REPORT NO. RTD ~~RDT~~-TDR-63-1025

FINAL REPORT

JUNE 1963

Volume I

ROCKET PROPULSION LABORATORY
RESEARCH & TECHNOLOGY DIVISION
AIR FORCE SYSTEMS COMMAND
EDWARDS, CALIFORNIA

PROJECT NO. 8172

TASK NO.817201

PREPARED UNDER CONTRACT NO. AF 04 (611) -8187
BY
AMERICAN MACHINE & FOUNDRY COMPANY
GENERAL ENGINEERING DIVISION
STAMFORD CONN.

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Project No. 8172 Task No. 817201

PREPARED UNDER CONTRACT NO. AF 04(611)-8187

By: W. Rosenbaum and R. Abramowitz

AMERICAN MACHINE & FOUNDRY COMPANY
GENERAL ENGINEERING DIVISION
STAMFORD, CONNECTICUT

FOREWORD

This report has been prepared in fulfillment of the requirements of the study of Aerospace Ground Equipment for Large Solid Propellant Rocket Motors for the Rocket Propulsion Laboratory, Edwards, California, under Contract Number AF 04(611)-8187. The study was performed under the direction of Mr. E. W. Krajewski, Manager of American Machine & Foundry Company's Ground Systems Department. Mr. W. Rosenbaum was Project Manager and Mr. R. Abramowitz - Project Engineer. The work of defining the requirements which large solid propellant rocket motors would impose on Aerospace Ground Equipment was performed by Mr. William Hammond under the direction of Mr. Howard Kauffman, both of United Technology Center. The aid and guidance of the Rocket Propulsion Laboratory Project Monitor, Mr. Lee B. Thompson, is gratefully acknowledged.

ABSTRACT

This report describes the investigations accomplished during AMF's study of Aerospace Ground Equipment for Large Solid Propellant Rocket Motors. The work performed during the study encompassed the following:

1) An extensive survey of government agencies and industry firms to compile available information and advanced thinking in areas of equipment, transportation and handling techniques as applied to Large Solid Propellant Rocket Motors.

2) Review of existing studies and abstracting of the most promising available documents for use as background material.

3) Compilation and evaluation of concepts for handling, transportation, static test, and assembly-to-upper-vehicle stages of the Large Solid Propellant Rocket Motors.

4) Establishment of detailed handling procedures for solid propellant rocket motor components at the manufacturer's site, static test area and launch site.

5) Establishing of budgetary costs for the equipment involved.

6) Determination of potential problems in AGE development and identification of areas where future R&D funding could profitably be applied.

The study is intended to establish preliminary criteria for guiding subsequent AGE developers likely to be engaged by the Air Force in specific weapon system programs.

NOTE: Publication of this technical documentary report does not constitute Air Force approval of the report findings or conclusions. It is published only for the exchange and stimulation of ideas.

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SECTION I
INTRODUCTION

1. GENERAL

This report describes the investigations accomplished during AMF's study of Aerospace Ground Equipment for Large Solid Propellant Rocket Motors.

The report was prepared under the auspices of the Rocket Propulsion Laboratory, R&TD, AFSC, Edwards, California, (Lee B. Thompson, Project Monitor).

A major portion of the effort was accomplished by United Technology Center who, as AMF's subcontractor, established the requirements imposed by solid propellant motor components on Aerospace Ground Equipment.

The study is intended to be an aid to organizations engaged in the design and selection of equipment of the type discussed in this report.

2. SCOPE AND OBJECTIVES

The scope of the effort included a study of all Aerospace Ground Equipment which will be required in the handling of large solid propellant motors at the manufacturer's plant, during long distance transportation, at the static test facility and at the launch facility. To implement this effort, the following tasks were performed:

1) A search of applicable existing equipment within the military and in use by industrial firms.

2) A definition of potential modifications which would make existing equipment suitable for this purpose.

3) A concept and design criteria effort which defined the new equipment required.

4) A recommendation of areas for future effort which became apparent during the study.

Study objectives were:

1) To assemble existing data on large solid propellant booster studies, to establish current support equipment characteristics and to determine requirements for future systems.

2) To evaluate the capability of presently available commercial and military equipment to satisfy AGE requirements for large solid propellant motors and to investigate the extent of modifications required.

3) To provide preliminary criteria which will be useful to solid motor and weapon system designers and to pinpoint those areas which could conceivably result in large savings in AGE (Multi-Purpose Equipment.)

4) To establish preliminary criteria for guiding subsequent AGE developers likely to be engaged by the Air Force in specific Weapon System Programs.

3. CHRONOLOGY AND STUDY APPROACH

Work was started on May 1, 1962.

AMF submitted two quarterly reports which were distributed to interested parties within the Air Force and industry.

This document represents the final report and contains all pertinent material previously submitted in the quarterly reports.

AMF's Technical Effort ended on February 15, 1963.

A brief outline of the approach followed during the course of the effort is supplied below.

a. Letter Survey.

Early in the program and continuing throughout its duration, AMF conducted a letter survey aimed at compiling information which would be of use in meeting the study objectives.

Initial form letters were followed up with detailed inquiries where response indicated that this was warranted. Organizations were invited to

supply specifications, cost data and conceptual thinking in areas covered by the study.

The letter survey was directed into three general areas:

1) Equipment Suppliers - The aim was to obtain information on available equipment (specifications and cost data) and to solicit opinions as to the degree of modification which would be feasible when uprating of existing equipment was considered.

2) Transportation Companies - Common Carriers (Rail, Truck and Ship/Barge) - The aim was to obtain shipping rates and routes together with opinions of anticipated difficulties.

3) Government Agencies - Agencies contacted were concerned with: Handling of explosives (U. S. Coast Guard, Local Port authorities, etc.); Availability of Off-loading equipment at Ports (Local Corps of Engineers offices, Habor masters, etc.); and Overland Transportation of Heavy Loads (State Governments and agencies ruling on overweight and over-dimension permits).

Approximately 400 letters were sent during the survey. The results are compiled in Appendices A and B of this report.

b. Trips.

Supplementary to the letter survey, a number of trips were taken by AMF personnel, in many cases accompanied by Mr. L. B. Thompson, Project Monitor for the study. The purposes of the trips were:

1) To visit the various solid propellant rocket manufacturers to explain the program and to enlist their help in the effort.

2) To visit various NASA and DOD agencies for the purpose of enlisting their help in the effort and to obtain information about available heavy handling equipment and its limitations. Of particular interest was information concerning future space vehicle systems using solid propellant motors that were envisioned by these agencies.

A list of organizations visited together with information received can be found in Appendix B.

c. Survey of Existing Studies.

One of the stated objectives of the study was to "assemble existing data on large solid propellant booster studies". Consequently as many of these studies as were available were reviewed. Those exhibiting information of interest to this effort were abstracted.

A complete list of all documents reviewed may be found in Appendix C. The documents abstracted are noted. It is felt that the abstracts will provide valuable background to future designers of AGE for the large solid propellant motors. In view of the classified nature of most of the studies, the abstracts are submitted as a classified appendix to this report. They may be obtained through Headquarters Rocket Propulsion Laboratory, Research and Technology Division, Edwards AFB, California on a "need to know" basis.

d. Establishment of Areas of Activity and Related Functional Requirements.

This effort was performed by United Technology Center, acting as subcontractor to AMF on the study. UTC established all of the functional requirements for the motor components at the manufacturing, static test and launch facilities, as well as procedures for the handling, inspection and assembling of these motors. The results of this effort can be found in Section 6.

e. Establishment of Operational and Site Constraints.

Before AGE can be specified, additional criteria (above and beyond motor requirements) must be established. These criteria will establish the requirements imposed upon the AGE by the peculiar operational needs associated with handling and long line transporting of large solid motor components.

A limited effort was performed in this area in order to enable AGE developers to select applicable equipment for the various solid propellant motor components. (See Section 4).

f. Establishment of Equipment Requirements.

Following the determination of the physical characteristics of the solid motors and their components, and the establishment of operational and site constraints, the applicability of equipment was determined.

Equipment shown is projected on the basis of information received from the industry letter survey, and on new equipment concepts generated.

g. Equipment Not Commercially Available.

Where equipment is not commercially available, applicable concepts are discussed in Section 5.

h. Parametric Study of Launch Rate vs. AGE Cost.

A parametric study of launch rate vs. AGE cost for the three sites associated with solid propellant motor handling (manufacturing, static test and launch) was made for both the 120 and 156-inch segmented approaches. As part of this study, costs for the equipment were established. Costs were determined by utilizing vendor information, previous experience and engineering judgement. The results of these studies may be found in Section 7.

Cost of transportation was treated separately and the data to be used in determining cost vs. launch rate for any particular route chosen may be found in Section 9.

The 260-inch motor did not lend itself to the above-mentioned type of parametric study because the handling concepts could not be definitized to any great extent.

i. Concept Evaluation — 260-Inch Motor Manufacturing/Static Test Facility.

An evaluation of representative concepts (both wet and dry) for a 260-inch monolithic motor manufacturing/static test site was made. Concepts were evaluated by applying engineering judgement to a number of evaluation parameters. For the results of the evaluation refer to Section 11.

j. Determination of Areas for Additional Study.

Section 13 outlines a number of areas to which future effort can be profitably applied. These areas encompass state-of-the-art advances as well as potential problem areas which may be encountered by presently contemplated AGE

SECTION 2
MOTOR AND VEHICLE TYPES CONSIDERED

1. MOTOR TYPES

A great number of solid propellant rocket motor configurations have been proposed in recent years for ICBM and space vehicle applications. Sizes considered have ranged from 100-inch diameter segmented through 320-inch diameter unitized (Monolithic) motors.

The present study effort was to be made as all encompassing as possible within the time and funding limitations imposed.

To make the study meaningful, three definite motor configurations were selected:

1) 120-inch diameter segmented (used for the 624A system).

2) 156-inch diameter segmented (considered for an advanced version of the 624A system and for the Saturn series).

3) 260-inch diameter monolithic (considered for NOVA type vehicle applications).

It is believed that equipment and costs for any of the sizes falling between or in close proximity to the extremes of the above range, may be determined by interpolating the data presented in this report.

Before the three motor configurations mentioned above were selected for detailed study, a number of others were considered:

1) Various sizes of segmented motors.
2) Pie-shaped - externally wound.
3) Various sizes of monolithics.
4) Motors using the GEL propellant technology.

A brief explanation of each is supplied below. Additional details may be found in other parts of this report as indicated.

a. Segmented Motor.

The segmented motor design concept is easily pictured by considering

a standard rocket sliced along planes perpendicular to the motor's longitudinal axis (Figure 2-1B, Page 2-4).The resultant sections are known as the head-end segment, the circular segment, and the aft-end segment. Each segment is loaded with propellant, and when the segments are joined together, a complete rocket motor is formed.

A discussion of the segmented motor approach may be found in Section 6.

b. Unitized Motor (Monolithic).

The unitized motor concept involves the loading of propellant into a single piece rocket motor case (Figure 2-1A, Page 2- 4) at or near the test site. The concept requires a minimum of transportation for the complete motor but because of the large size and weight (260 inches diameter - 1400 inches long - 3, 157, 000 lbs.) the handling requirements dictate the use of equipment and techniques that are not currently available. Further details of the monolithic motor may be found in Section 6.

c. Externally Wound, Pie-Shaped, Segmented Motor.

This concept consists of placing inhibited, pie-shaped segmented sections side by side to form a ring and stacking layer after layer of these rings to form a complete motor. (Figure 2-1C, Page 2- 4). Filament windings are placed over the joints to keep the layers in place. After completion of the stacking operation, the grain segments are encased by the glass fiber filament winding technique shown in Figure 2-1D, Page 2- 4. More details about this concept may be found in Section 3.

d. GEL Propellant.

A propellant which has been extensively discussed in the literature, but which to date, has not found any practical use for large space vehicles, is the GEL type of solid propellant. This type of propellant can be handled at the pad in a manner similar to liquid propellant, thereby eliminating the handling problems associated with the segmented and monolithic solid propellant motors. For further details of this approach, refer to Section 3.

2. VEHICLE TYPES

The types of vehicles considered for solid propellant motor use do not affect the handling procedure for the solid motor components to any great

extent. The booster assembly procedure is the only area affected by vehicle type. This study considers two general configurations for clustering. They are:

1) The segmented solid propellant motors next to a liquid core (624A type vehicle using 120 or 156-inch motor segments).

2) The Saturn and Nova type vehicles which would use solid propellant first stages, consisting of segmented or monolithic motors in clusters of three or more.

Figure 2-2, page 2-5 illustrates typical vehicle configurations. Concepts for booster assembly of both segmented and monolithic motors can be found in Section 5.

FOR DISCUSSION REFER TO PAGE 2-2

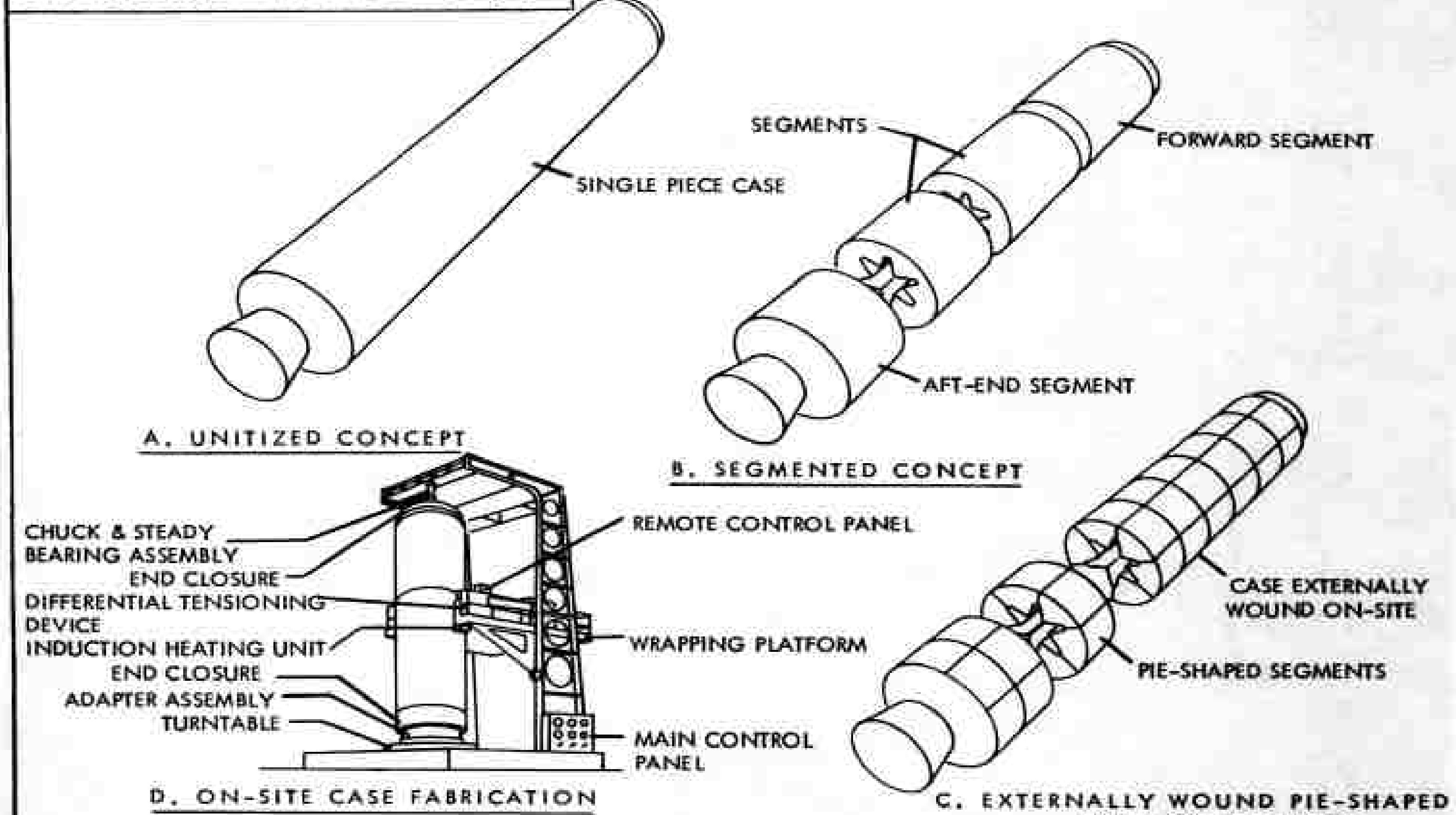


FIGURE 2-1
SOLID PROPELLANT ROCKET MOTOR CONFIGURATIONS

FOR DISCUSSION REFER TO PAGE 2-3

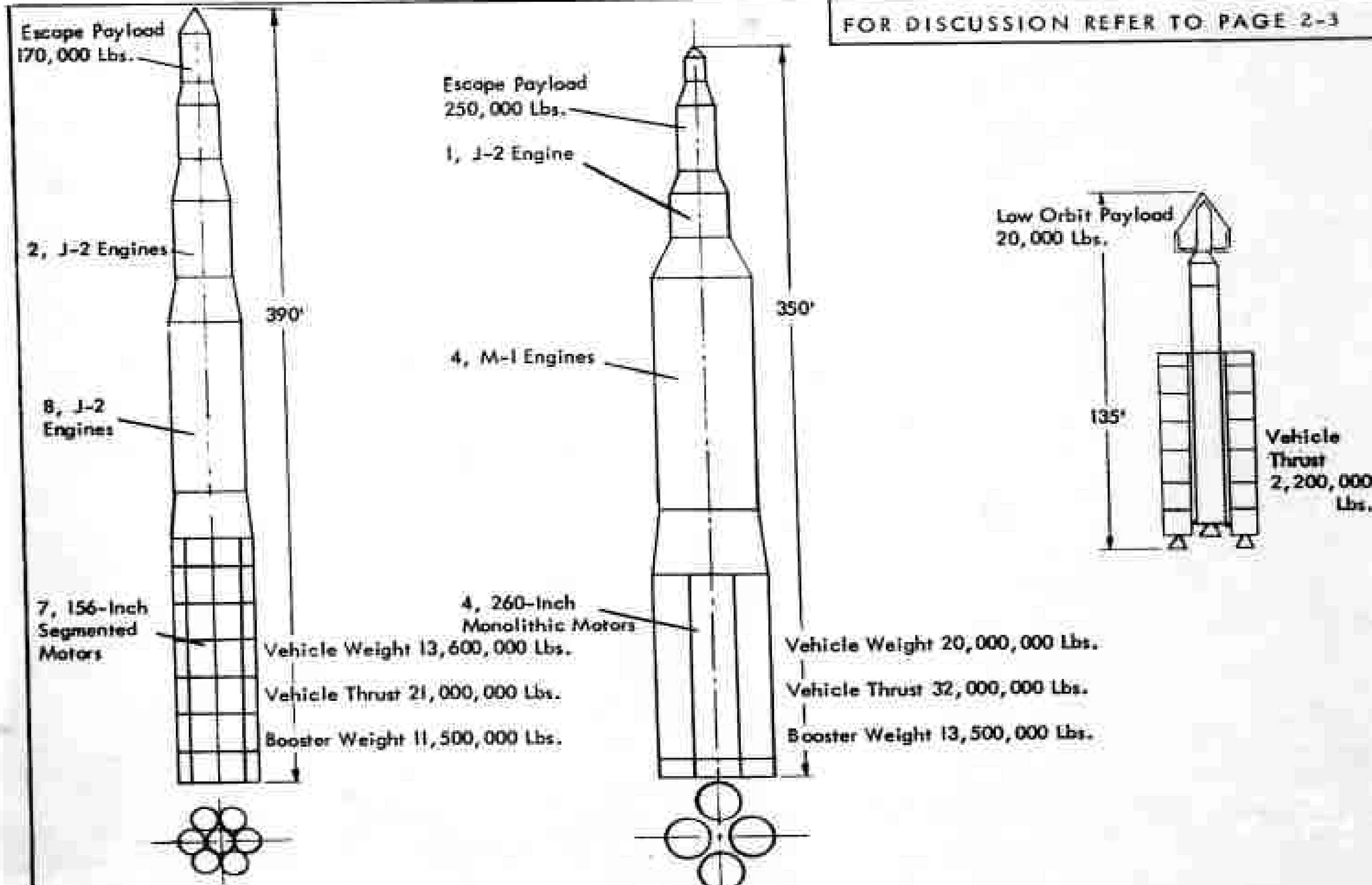


FIGURE 2-2
TYPICAL VEHICLES UTILIZING SOLID BOOSTERS

SECTION 3
SOLID PROPELLANT MOTOR LOGISTIC CONSIDERATIONS

1. GENERAL

In the solid-chemical rocket, the fuel and oxidizer are intimately mixed together and cast into a solid mass (grain). The propellant grain is firmly cemented to the inside of the case (metal or plastic) and cast with an opening down the center. After being ignited by a pyrotechnic device, which is usually triggered by an electrical impulse, the propellant grain burns on the inside surface of the opening. The hot combustion gases pass down the grain and are ejected through the nozzle to produce thrust.

The probable utilization of solid propellant motors in the US space program has been discussed briefly in Section 2. A short discussion of the advantages of using solid propellant motors is in order at this point. Their chief advantage over liquid systems is the fact that they can remain in stand-by status for long periods while still being ready for almost immediate firing when necessary. Further, in addition to high reliability in launchings, their development periods are generally briefer than those of other propulsion systems.

The basic problem with solid motors is the fact that motor components of unprecedented sizes and weights must be handled and transported. In order to alleviate this problem, two basic approaches to the design of solid propellant motors have been considered, (1) segmentizing and (2) the GEL technique. Both techniques tend to permit the utilization of standard transportation equipment although, for the larger sizes, special equipment will have to be developed.

Another method of building solid motors of large thrust capacity is by casting a complete motor or large diameter and height (unitized approach). Special transportation and handling techniques must be developed in this case.

Additional components of both the segmented and the unitized approach which require mentioning are the following:

1) Forward and Aft Closures - Those components which are required to close the bottom and the top of a stack of cylindrical segments. The forward closure serves as a mounting fixture for the igniter; the aft closure. supports the nozzle.

2) Nozzle - The nozzle is required to convert the gases issuing out of the combustion chamber (made up of the case walls on the side and the forward closure on the top) into usable thrust. The shape of the nozzle is such that maximum thrust is produced.

3) Thrust Termination System - A system used for terminating the thrust of a solid propellant motor at a predetermined time. This is accomplished by blowing off covers in the Forward Closure of the motor so that the gases may escape out of the openings as well as out of the nozzle. In this way, the chamber pressure is reduced and the effective thrust neutralized.

4) Destruct System - A system used to destroy the solid propellant motor on takeoff or in flight if necessary. Destruction is performed by a series of explosive charges placed along the motor. When these charges are set off, the motor breaks up into small pieces and is thus disintegrated.

Further details on the segmented and unitized approaches may be found in Section 6.

Only the cylindrical segments and the unitized motor are being actively pursued by the present planners of space vehicles in the Air Force and NASA.

Before a motor can be declared suitable for operational use, considerable static testing must be performed. In the case of solid motor development, the trend has been to static test the assembled motors in the nozzle up position. In this way thrust can be conveniently measured by load cells placed under the forward closure while the heavy thrust loads are reacted directly into the concrete foundation. Additional purposes of the static test are:

1) Verification of the structural integrity of the motor case.

2) Testing of the thrust vector control system.

3) Verification of the Ignition system.

4) Determination of the effects of temperature variation on propellant performance.

5) Verification of the thrust termination system (if any) and the destruct system.

2. CYLINDRICAL SEGMENTS

a. Manufacture.

The casting of cylindrical segments is performed at the manufacturer's plant. Basic steps in the manufacturing process are:

1) The motor segment case with the insulating liner is placed into the casting pit with its central axis vertical.

2) A mandrel is placed along the central axis of the motor case.

3) The premixed propellant is poured into the pit between the mandrel and the insulating liner.

4) After the curing period, the mandrel is removed and the cast segment is withdrawn from the pit and transported to the Inspection Station.

5) Following inspection, the segment is prepared for long distance shipment.

Provisions for handling and protecting the segments during these operations are required. The segment case is primarily designed to fulfill its function during vehicle flight. It is thus as thin as is consistent with the internal pressure developed during the burning period. In order to facilitate the lifting of the motor segment, special handling rings are required. These handling rings also serve the secondary function of keeping the segment round during transit and subsequent storage.

Additional equipment required for the segments in the manufacturing area consists of transfer dollies, overhead cranes and weather protection.

b. Inspection.

Inspection of propellant-containing components of motors consists of checking for the following types of defects:

1) Propellant-Liner Separation.
2) Liner-Case Separation.
3) Cracks and Fissures in the Cast.
4) Voids and porosity in the Cast.
5) Propellant Non-Uniformity.
6) Uneven Curing.

A combination of visual, radiographic, and Ultrasonic inspection techniques are utilized. Details of these techniques and their use will be found in Section 10.

c. <u>Environmental Restrictions.</u>

During long line transportation, provisions must be made to keep the segment within acceptable environment limits. Environmental restrictions include the following:

1) Temperature limits 60 - 90 degrees F.
2) Relative humidity not to exceed 50 percent.
3) Shock input not to exceed 10 g's in any plane.

d. <u>Long Distance Transportation.</u>

The transportation of the solid propellant motor components to the launch or static test site presents a severe problem. Cylindrical segments presently considered have the following dimensions and weights:

	Length, in.	Weight, lbs.
120-inch segment	130	80,000
156-inch segment	288	270,000

The 156-inch segment can be transported by rail if extreme caution is taken (i.e., slow speeds, special routes, etc.)

Truck transportation of these segments is possible but quite cumbersome in view of the many overweight and over-dimensions restrictions imposed by various states.

Water transportation is, of course, the most feasible mode. However, water transportation in most cases requires a preliminary step of rail or truck transportation before the motor segment arrives at a dock loading facility. Moreover, if the starting point of water transportation is somewhere on the

west coast and the destination the Atlantic Missile Range, the undesirable requirement passing through the Panama Canal presents itself. For more details on long line transportation, refer to Section 9.

The transportation problem is further aggravated by the somewhat hazardous nature of the propellant, which is defined as Class "B" in the Interstate Commerce Commission Regulation, Tariff No. 13. In essence, the classification of Class "B" means that, in its condition as transported, the propellant will function by rapid combustion rather than detonation.

The above restrictions dictate the use of environmentally-controlled containers for the segments during long line transport.

In addition, it is necessary that the segment be protected against willful damage by snipers using small arms. A typical specification of which containers should be designed would protect them from 30 caliber armor-piercing ammunition fired at a distance of 100 yards.

Shock mitigation is not usually required where truck transportation is used. Rail transportation, however, does necessitate the incorporation of devices which attenuate the shocks due to rail car "humping". The use of cushioned connecting links is contemplated in this instance (see Section 9). The segment will be accompanied by appropriate sensing and recording instrumentation, which will tell personnel at the destination whether any of the abovementioned environmental limits has been exceeded. If this is the case, such a segment would then be given a thorough inspection to determine whether storage for further use is indicated.

e. Storage of Segments.

Storage of the solid propellant segments is contemplated once they arrive at the launch site. It may also be necessary to store segments at the manufacturer's plant or at some intermediate transfer point. In view of the hazardous nature of the segments, it is necessary that their concentration at any one point be limited. In general, storage areas are arranged so that no more than a maximum of 500,000 pounds of propellant is maintained in any one compound. Each storage area is surrounded by earth embankments in order to limit the effects of a possible explosion. Segments are stored in individual cubicles with a fire retarding wall in between. For a more detailed discussion of the facility spacing criteria as they affect solid propellant components, refer to Section 4.

Storage of segments on barges has also been suggested. This concept is feasible where barge transportation is contemplated. Trade-offs between the cost of a storage facility and the cost of utilizing barges as storage facilities will have to be made before the barge storage concept can be accepted.

f. Segment Handling and Transportation Equipment at Static Test and Launch Site.

At the manufacturer's facility, equipment for handling and local transportation is required. It is desirable that such equipment be identical to that used at the manufacturer's plant where feasible. In this way, standardization of AGE components will become possible.

g. Assembly of Segments into Motors.

Basically, the assembly of segments into motors consists of the following steps:

1) Place nozzle-aft closure assembly on a fixture with the nozzle down.

2) Assemble segment after segment on top of each other.

3) Install top closure.

4) Final steps include the leak checking of joints with pneumatic pressure and the installation of igniter, thrust termination and destruct system.

For more details, refer to Section 6.

h. Assembly of Motors to Parallel or Upper Stages.

Motor assembly may be accomplished either on or off the launch pad.

(1) On-Pad Assembly.

This technique makes use of the gantry existing at the launch pad for the stacking of segments into motors. This method is suitable only where low launch rates are contemplated, since it ties up the launch pad during the motor assembly operation. For more details, refer to Section 5.

(2) Integrated Transfer and Launch (ITL Off-Pad Assembly).

For higher launch rates (more than 10 a year), it is desirable to perform as many of the needed assembly operations as possible off the launch pad. To this end, separate solid motor assembly facilities are planned. The stacking of segments into motors will be performed at these auxiliary facilities. Mating of the solid motors to parallel or upper stages will also occur off the pad. The completely assembled space vehicle will then be brought to the pad in the vertical attitude. In this way, the launch pad is tied up only for the actual launch procedures. Thus, many more launches can be accomplished from the same pad than with a system which features on-pad assembly. For more details, refer to Sections 5 and 6.

3. UNITIZED MOTOR

a. Manufacture.

The casting of the unitized motor is performed at a facility which will be located relatively close to the launch site. Basic steps in the manufacturing process are as follows:

1) The empty motor case is brought to the manufacturing facility and erected.

2) A mandrel is placed along the central axis of the motor case.

3) The mixed propellant is poured into the case between the mandrel and insulating liner.

4) After the curing period, the mandrel is removed and the motor is inspected.

With the completion of step 4), two alternate routes are open:

1) Static Testing of the Motor.

a) The nozzle is emplaced and the motor is static tested.

b) The empty motor case is removed.

2) Motor prepared for Long Distance Shipment to the Launch Site.

a) The motor is prepared for long distance shipment.

b) The motor is transferred to the horizontal and shipped.

b. Long Distance Transportation.

Long distance transportation of the unitized motor becomes a very cumbersome problem in view of its very large size and weight. (Length 120 feet, weight over 3 million pounds). Methods suggested utilize barge transportation for the actual travel portion. A number of different schemes are being proposed for erection and handling at the manufacturing/static test site and the launch site. These methods are discussed in detail in Section 5.

NOTE: 1) Environmental restrictions are the same as those discussed for the cylindrical segments. (See Page 3-4 of this section).

2) Manufacturing and static testing are performed at the same location.

c. Assembly of Motor Stages.

As previously discussed for the segmented approach, both the on-pad assembly and ITL approaches can be utilized for the handling of the unitized motor. Concepts for each approach may be found in Section 5.

4. PIE-SHAPED SEGMENTS

The concept of pie-shaped segmented solid motors was developed by the Hercules Powder Company of Wilmington, Delaware. In essence, this concept consists of stacking pieces of propellant and winding a fiberglass case around them. The maximum size of pie-shaped propellant would be based on usual shipping restrictions.

All propellant, case material and other components of the rocket motor would be transported to the assembly site by conventional overland means. Manufacturing of components would not occur at the launch site. The equipment required at the motor assembly site consists of a large gantry and a winding machine; both of these are rail-mounted.

Pie-shaped sectors are cast and cured in appropriate molds and assembled to form cylindrical segments. In order to prevent burning of the propellant along the sides of the sectors after they have been assembled, each pie sector is coated with an inhibitor. The size of the individual sector is as large as is consistent with transportation requirements. Depending on motor size, the approximate dimensions of a sector could be: (See Figure 3-1, page 3-12).

1) Width (arc length perifery ... 12 feet
2) Length .... 12 feet
3) Height .... 9 feet
4) Weight .... 100,000 lbs.

Because of the large final diameter of the assembled motor (which can be larger than the unitized motor discussed before), unique methods of assembling and emplacing the nozzle must be employed. These methods will require segmentizing the nozzle and its associated components (carbon insert, etc.) to ease handling.

Assembly of the motor itself is begun with the stacking of propellant sectors, which is accomplished with the aid of gantry and a center support structure. The center support structure would serve the purpose of locating or indexing the propellant sectors and could accommodate workmen. Both the nozzle mandrel and center support structure are removed after motor assembly.

The stacking process consists of lowering the sectors into place individually. When the first total segment (made up of a complete ring of sectors) is in place, circular windings of glass filaments (with epoxy resin) are applied up to within a foot of the top of the segment. The next set of sectors are then lowered into place and wound. The purpose of the winding is to hold the sectors in place during the stacking process. They do not necessarily form part of the pressure-withstanding case. This procedure is repeated, stepwise, until all the propellant sectors are in place. See Figure 3-2, page 3-12.

Following the stacking operation, the motor case itself is wound and cured. The filaments are impregnated with an epoxy resin as they are wound; the cure temperature can range from 75°F to 125°F. Helical windings are used for longitudinal strength and circumferential windings for girth strength. The winding takes place with the motor remaining in a fixed position. The winding heads are designed for both rotary and vertical motion. The winding and curing are followed by removal of the center structure, at which time the finished rocket can be moved by gantry to the launch pad.

The use of pie-shaped sectors would ease the transportation problem associated with large, heavy solid motors. However, motor assembly would require very extensive winding equipment at the launch site. Assembly on the launch pad would require considerable time. Provisions would have to be made for moving the winding facility away from the pad prior to launch.

5. GEL SOLID PROPELLANT

As mentioned previously, another method of overcoming the transportation restrictions is the "GEL solid approach".

The basis of this new concept is the GEL-solid propellant employed. The propellant is a mixture of solid particles, such as metal, power and oxidizer, dispersed in a liquid carrier and gelling agent. In manufacture, the solids are mixed with the liquids in a conventional solid propellant mixer to form a viscous slurry (with a consistency similar to that of tooth paste). This material can be pumped like a liquid and performs ballistically as a solid propellant. Since no polymerization or solvation is necessary, propellant manufacture ends with the mixing step. (No curing occurs at the manufacturing facility.)

A typical design of a GEL solid motor can be found in Figure 3-3, page 3-13. The pressure vessel and nozzle of this motor are similar to solid propellant end-burning rockets. The major difference is that physical support of the GEL solid propellant is provided by the end closure of the motor and a tray structure in the center. A passageway for gas flow to the nozzle is provided through each propellant bed by an insulated standpipe. Upon ignition, the surface of each propellant bed ignites. Thereafter the burning surface regresses normal to itself until propellant depletion terminates the propulsive cycle. Throughout burning, the gases generated are ducted to the nozzle through the standpipes.

A major advantage of the GEL booster is the simplicity of logistics and operations. Propellant is mixed and inspected in a propellant plant and then loaded into commercial tank cars for shipment to the launching or holding site. The ability to transport the propellant via rail car permits launch sites to be located almost anywhere. The motor hardware is manufactured as required and components installed and shipped in completely inert form to the launch point. At the launching site, the booster motor is erected on the launching pad, and all the upperstages and payload are assembled and mounted to the booster hardware which is then ready for insertion of the GEL solid propellant. The entire operational sequence is depicted in Figure 3-4, page 3-14, supplied by the Atlantic Research Corp.

The GEL solid propellant technique would alleviate some of the transport problems associated with large solid motors. However, transfer facilities for the GEL propellant would be needed and could be expensive. Case transportation would still be a problem with regard to dimensions. This technique would require considerable pad time for motor completion and provisions would have to be made for moving the propellant loading equipment away from the pad.

FOR DISCUSSION
REFER TO PAGE 3-9

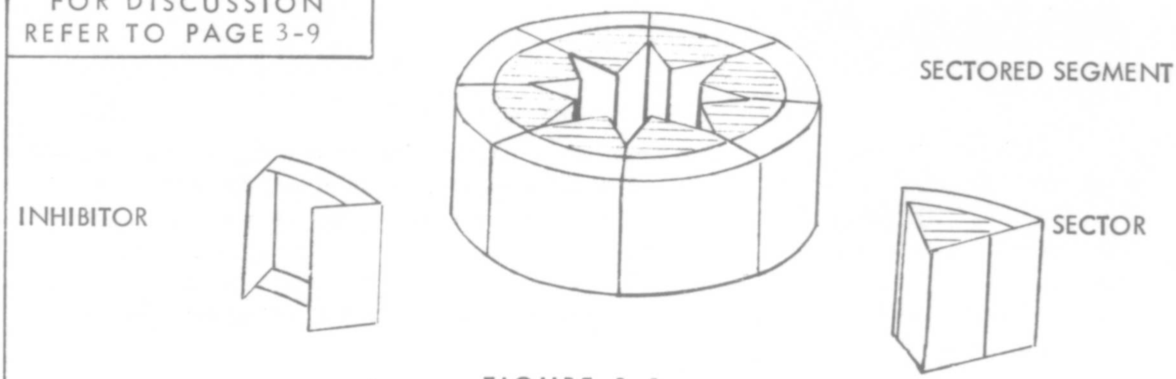


FIGURE 3-1

BASIC BUILDING BLOCKS OF THE PIE-SHAPE APPROACH
(SUPPLIED BY HERCULES POWDER CO.)

FOR DISCUSSION
REFER TO PAGE 3-9

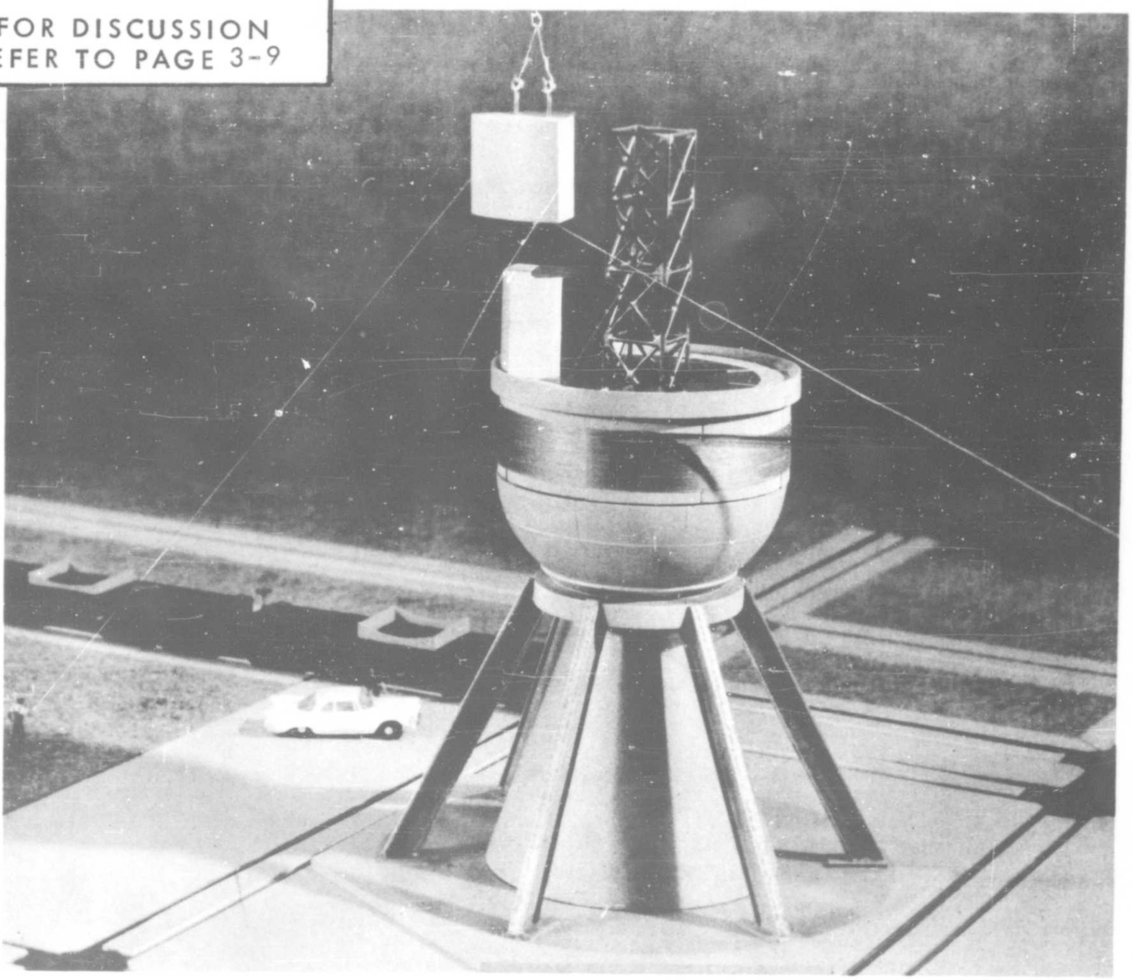


FIGURE 3-2

PIE-SHAPED-SECTOR-MOTOR ASSEMBLY CONCEPT
(SUPPLIED BY HERCULES POWDER CO.)

FOR DISCUSSION REFER TO PAGE 3-10

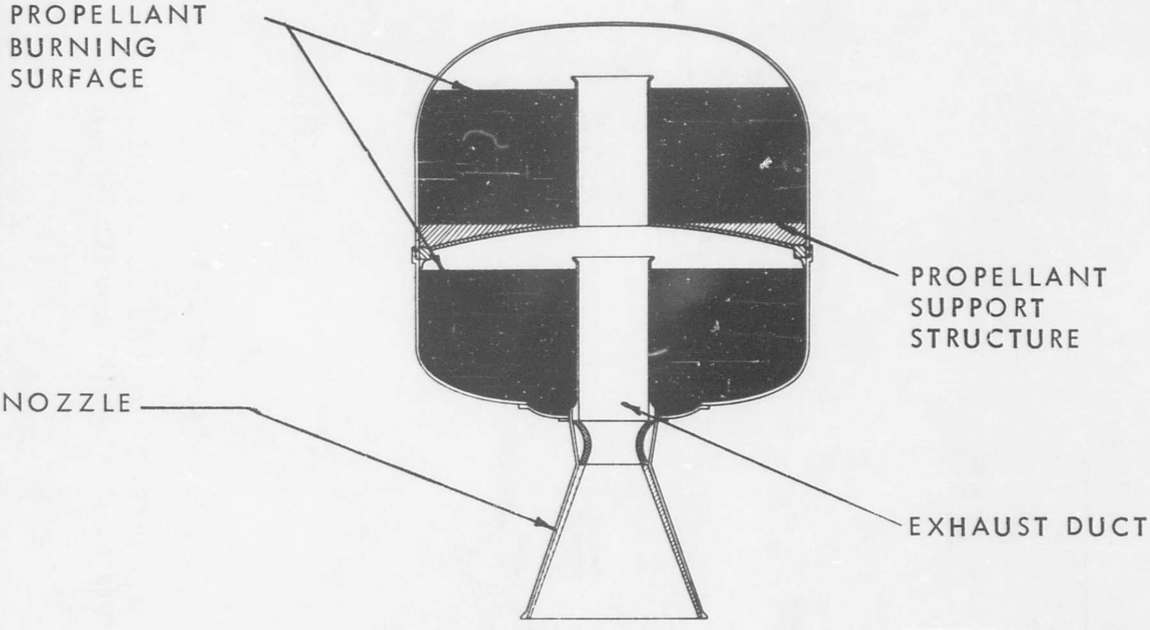


FIGURE 3-3

GEL SOLID MOTOR
(SUPPLIED BY ATLANTIC RESEARCH CORP.)

FOR DISCUSSION REFER TO PAGE 3-10

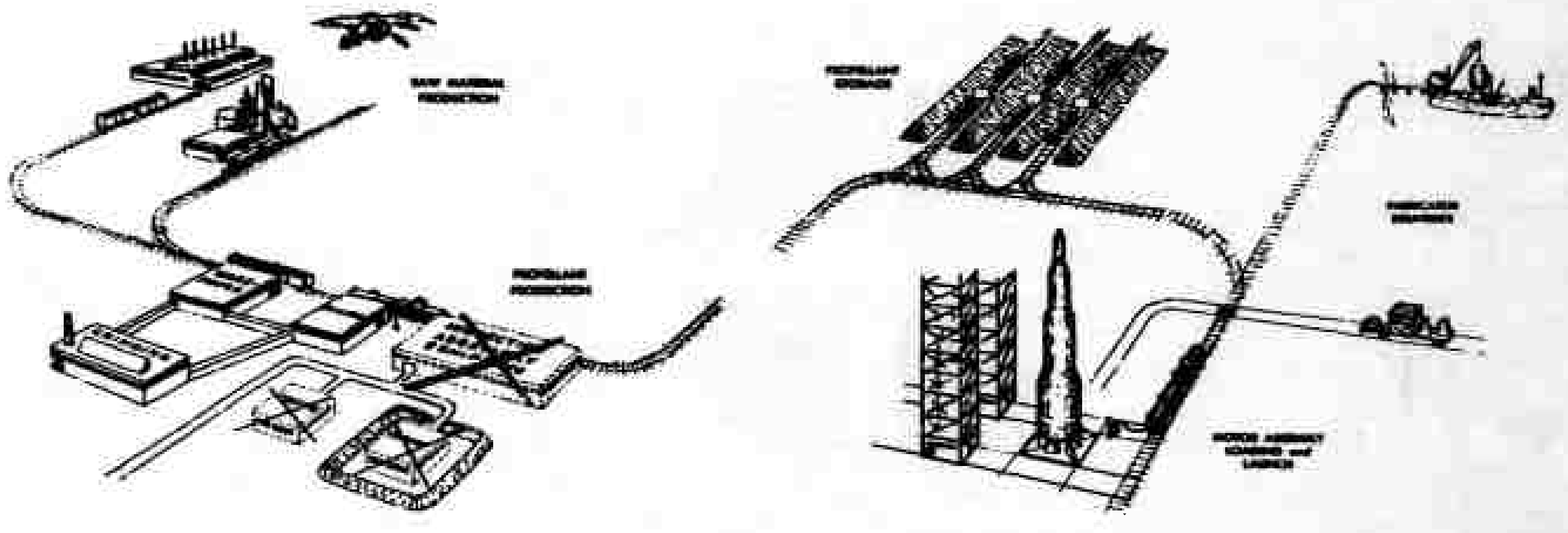


FIGURE 3-4

OPERATIONAL SYSTEM DEMONSTRATING THE LOGISTICS OF THE GEL SOLID BOOSTER
(SUPPLIED BY ATLANTIC RESEARCH CORP.)

SECTION 4
OPERATIONAL AND SITE CONSTRAINTS

1. GENERAL

Before equipment can be completely specified for eventual concepting, additional design criteria must be supplied. These criteria may be classified as either operational or site criteria.

2. OPERATIONAL CRITERIA

a. Operational Readiness of Equipment

AGE for the large solid motor booster programs should be designed so that replacements and breakdowns are minimized. In an operational system which services space vehicles tied to extremely critical time schedules (launch windows), this is an essential design parameter. These launch windows could be as short as several minutes (rendezvous operation) so that all possible care must be taken to insure absolute reliability of support equipment.

b. Standardization and Multi-Purpose Usage.

Certain items of equipment which will be subjected to continuous usage (shipping containers, transport dollies, etc.) can probably not be designed economically for the operating spans (10 years) envisioned without maintenance. Therefore, ease of maintenance is an important factor in component selection. In this connection, standardization should play a major role in minimizing the logistic problems associated with spare parts distribution. A typical example would be the differential in wheel loading required for a transport dolly for the 120 and the 156-inch segments. It would be highly desirable not to change wheel diameters, but instead, to add additional wheels.

Further exploration of this line of thinking leads one to the development of multi-purpose equipment, i. e., equipment which will be designed to perform more than one function - or the same function for more than one component. Such equipment may be modular in nature so that a combination of several small modules can be used to form a piece of equipment suitable for large and heavy load handling. Again, the modules should be designed for maximum standardization of components.

An example of the modular approach is presented in Figure 4-1,

page 4-7, supplied by Thiokol Chemical Corp. This system utilizes a pallet or pallets which are joined together to serve multipurpose functions. As proposed, one pallet will handle a 120-inch single segment or the associated nozzle. Two pallets coupled together would handle any one of the following:

1) Two 120-inch segments.
2) One 120-inch segment and its associated nozzle.
3) One 156-inch segment.
4) One 156-inch nozzle.

Each system would be provided with a protective cover and chocks (supports) compatible with the component or components being handled.

The basic module shown in Figure 4-1, page 4-7, is of box frame construction equipped with rollers for use in roll transfer. In addition, provisions for handling by forklift or slings are supplied. This facilitates handling of the lighter loads such as nozzles. Transportation tie-downs and module-to-module coupling are also provided. Each module would have a load carrying capacity of 150,000 pounds.

An additional feature which can be built into this concept is the provision for horizontal rotation of the segment. This could be accomplished by incorporating rollers into the chocks. This feature will permit radiographic inspection of the segments without removing them from the pallets.

c. Economic Considerations.

A prime aim of all AGE systems should be economy. This should not, however, be construed to mean that equipment per se must be the cheapest available. Other considerations will greatly contribute to the over-all economics of the entire system when considering a high degree of utilization over many years. As an example, it may be advantageous to design special multipurpose equipment at a relatively high development cost rather than to purchase and modify a piece of single purpose equipment which may already be available. In connection with this, as was previously pointed out, AMF found it quite difficult to obtain modification specifications from equipment manufacturers. In most cases the opinion of these manufacturers was that modification (increase in load carrying capacity) would require practically starting from scratch. It is possible, however, to add special attachments (slings, auxiliary hoists, etc.), to existing equipment, which will enable it to meet solid motor handling requirements within its capacity.

d. Transportability.

In view of the long distances existing between propellant manufacture, static test site and launch site, the AGE should be easily transportable by common carriers. Here again, a modular approach which would permit on-site construction of large pieces of handling equipment would have significant advantages. If modularization of a particular piece of equipment is not possible, field assembly of transportable parts must be a major consideration in the design.

e. Reliability.

Reliability is defined for the purpose of this report as the probability that equipment will function as envisioned for a specified life cycle. In view of the very costly and hazardous nature of the loads to be handled, reliability for all pieces of equipment must be very high. Particularly so, however, for equipment handling completely assembled boosters and space vehicles prior to and during launch. Equipment suppliers, therefore, should be fully aware of the high reliability requirements which must be placed on what normally would be considered "run of the mill" type hardware.

f. Design Against Hazards.

Equipment to handle solid propellant motor components must be designed for the potentially hazardous nature of the propellant. Solid propellants can be classed as either a fire, explosive or toxic hazard. Accordingly, the design of all equipment must consider the requirements of the National Board of Fire Underwriters and the appropriate military specifications covering these subjects.

3. SITE CRITERIA

a. Hazards and Safety Considerations (Quantity Distance).

The nature of solid propellants is such that, under adverse circumstances, rapid burning or actual detonation may take place. Accidental malfunction of motor components at any time from the start of motor processing until the vehicle is launched and clears the launch area, can possibly result in property loss and endanger personnel, equipment, and launch facilities in the surrounding motor handling areas.

Hazards in the handling, storing and assembling of components

containing solid propellant at the launch base can be minimized by providing barricades, spacing of facilities and equipment and by limiting the maximum quantity of propellants in any area.

The distance required between elements of a launch complex, so that an accidental explosion at one facility does not damage any of the other facilities or equipment, is a function of the quantity of the exploding material, its TNT equivalent value and the susceptibility to damage of the neighboring element.

In the evaluation of explosion damage to facilities and equipment the following effects must be considered:

1) Blast effects; i.e., the possible damage from overpressure and dynamic pressure.

2) Projectile effect; i.e., the possibility of a projectile hitting another component. For example, an on-pad explosion of a missile might project metal fragments which could damage an adjacent pad.

3) Acoustic Effect. The possibility of damage to personnel or equipment resulting from the noise of a vehicle launch. Electronic equipment, particularly, is sensitive to acoustic effects.

4) Fire Hazard; i.e., the possibility of damage to surrounding facilities, equipment and personnel resulting from a conflagration fed by solid propellant.

Figure 4-2, page 4-8 is a curve of Blast pressure vs. Scaled Distance. With the aid of this curve and the scaled distance formula presented, it is possible to arrive at a set of curves for quantity distance vs. TNT equivalent for a variety of overpressures. A set of these curves is presented in Figure 4-3, page 4-9. The representative overpressures used in plotting the curve were:

1) .2 psi - Limit established for uncontrolled areas. (No significant damage to personnel or facilities will occur).

2) . 4 psi - Limit established for unprotected personnel. (Projected for spacing between the launch pads and industrial areas of the Saturn and Nova Launch complexes).

3) . 75 psi - Assumed limit for overpressure that representative vehicles may withstand.

4) 2. 0 psi - Limit for windowless, slightly reinforced construction established for uncontrolled areas.

5) 5. 0 psi - Overpressure that humans can withstand without any lasting effects.

In order to ascertain the quantities of equivalent TNT to be considered, one has to take into account the type of propellants being used. In general, the propellants are either Class 2 (20% TNT equivalent) or Class 9 (100% TNT equivalent). Liquid Propellant TNT equivalents must also be considered.

b. Soil Conditions.

Equipment designed to operate near launch sites must take into account the existing soil conditions. For example, equipment which operates at the Atlantic Missile Range should be designed to subject the soil to a load of no more than 3000 lbs. per square foot. This consideration will impose unusual wheel and axle designs for given loads.

c. Special Requirements.

Again, using AMR as an example, equipment must be designed to withstand the highly corrosive salt water atmosphere prevailing in that area. In addition to this corrosive environment, consideration must also be given to the existing wind profiles and extremes of temperatures to be encountered.

In connection with wind profiles, consideration must be given to equipment which is required to withstand very unusual weather conditions (hurricanes) and equipment which must perform its function under the worst weather conditions envisioned for operation of the launch complex.

Some typical values for operation at AMR are the following:

1) Transportation of complete vehicles (ITL) must be performed under wind conditions of 40 knot steady winds with 60 knot gusts.

2) Certain types of equipment which are part of the launch pad itself (gantries and space vehicles on pad) must be able to withstand hurricane winds of 125 mph. Under these conditions, however, such equipment may be provided with special tie downs.

This particular criteria, which is presently in use at Cape Canaveral, is based on information previously established and verified by the United States Weather Bureau, the National Bureau of Standards and the American Standard Building Code requirements.

The above criteria would also be typical for any subtropical climate.

In the case of the Pacific Missile Range (PMR) earthquake effects and high tides which are prevalent in that part of the country must be considered when specifying equipment and facilities. Where launch facilities are contemplated for other areas (Northern Alaska, etc.), climatic extremes which may be encountered, must be specified for proper equipment design.

Future military systems utilizing large solid propellant rocket motors must consider protection from enemy attack (i. e., hardening). Launch sites which consider this type of protection would be radically different from the launch sites shown in the concept section of this report. Substantial hardening is best accomplished by building underground sites which become "soft" only during the period of actual launch. Important considerations are reaction time, vehicle fragility as well as command and control requirements.

FOR DISCUSSION REFER TO PAGE 4-2

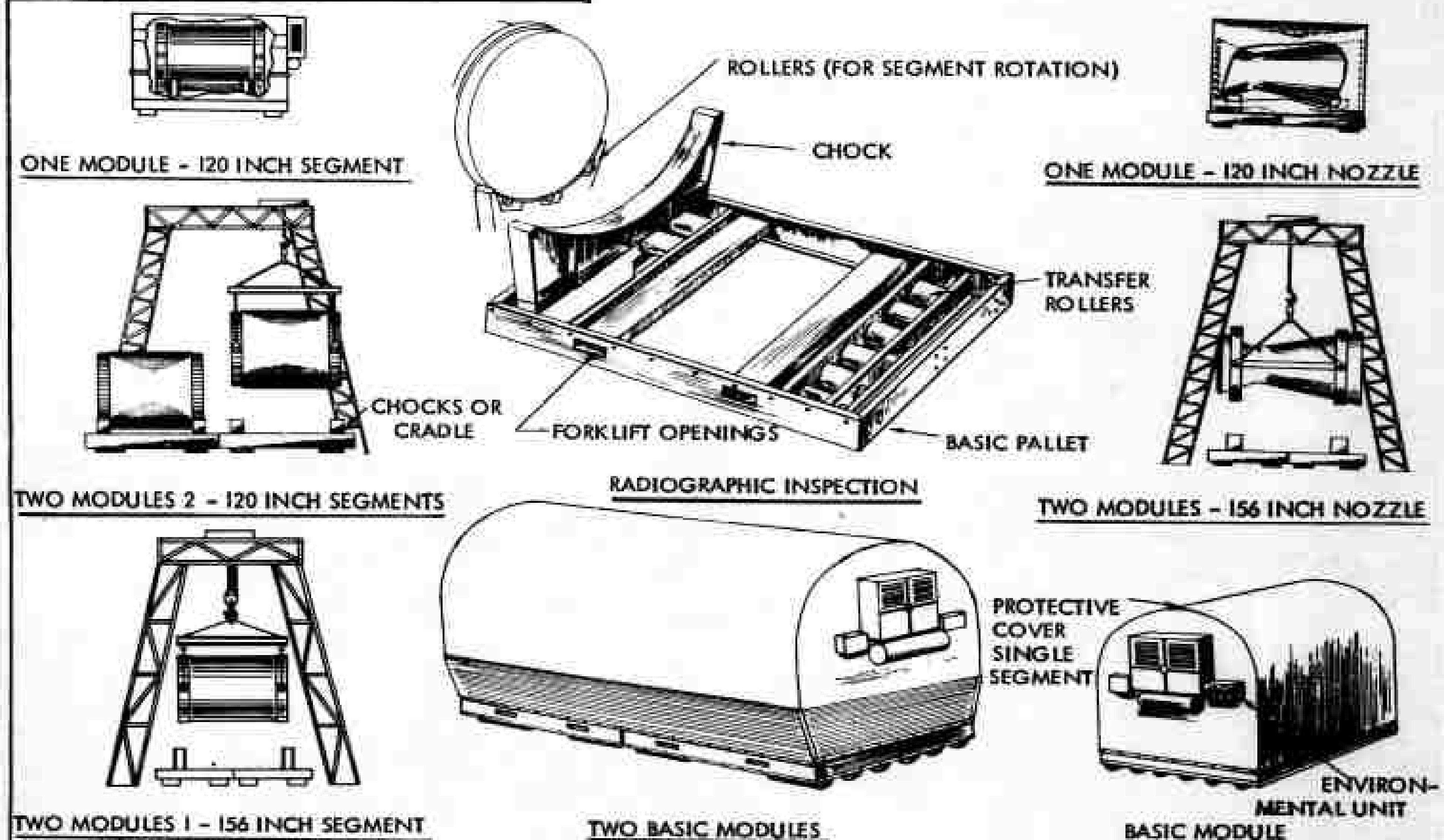


FIGURE 4-1
MODULAR HANDLING CONCEPT
(SUPPLIED BY THE THIOKOL CHEMICAL CORP.)

FOR DISCUSSION REFER TO PAGE 4-4

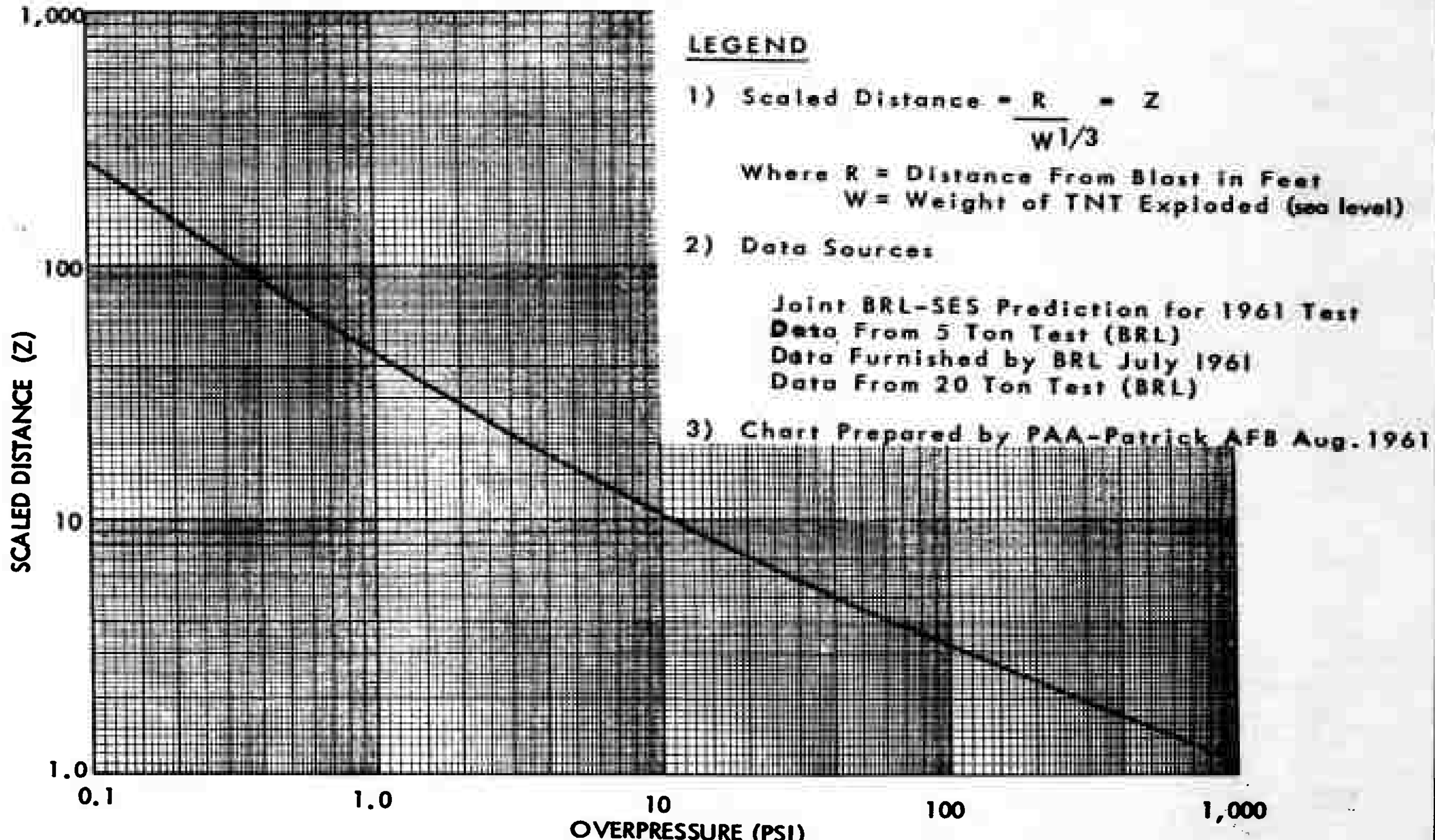


FIGURE 4-2

BLAST PRESSURE VERSUS SCALED DISTANCE FOR A TNT SURFACE BURST

FOR DISCUSSION REFER TO PAGE 4-4

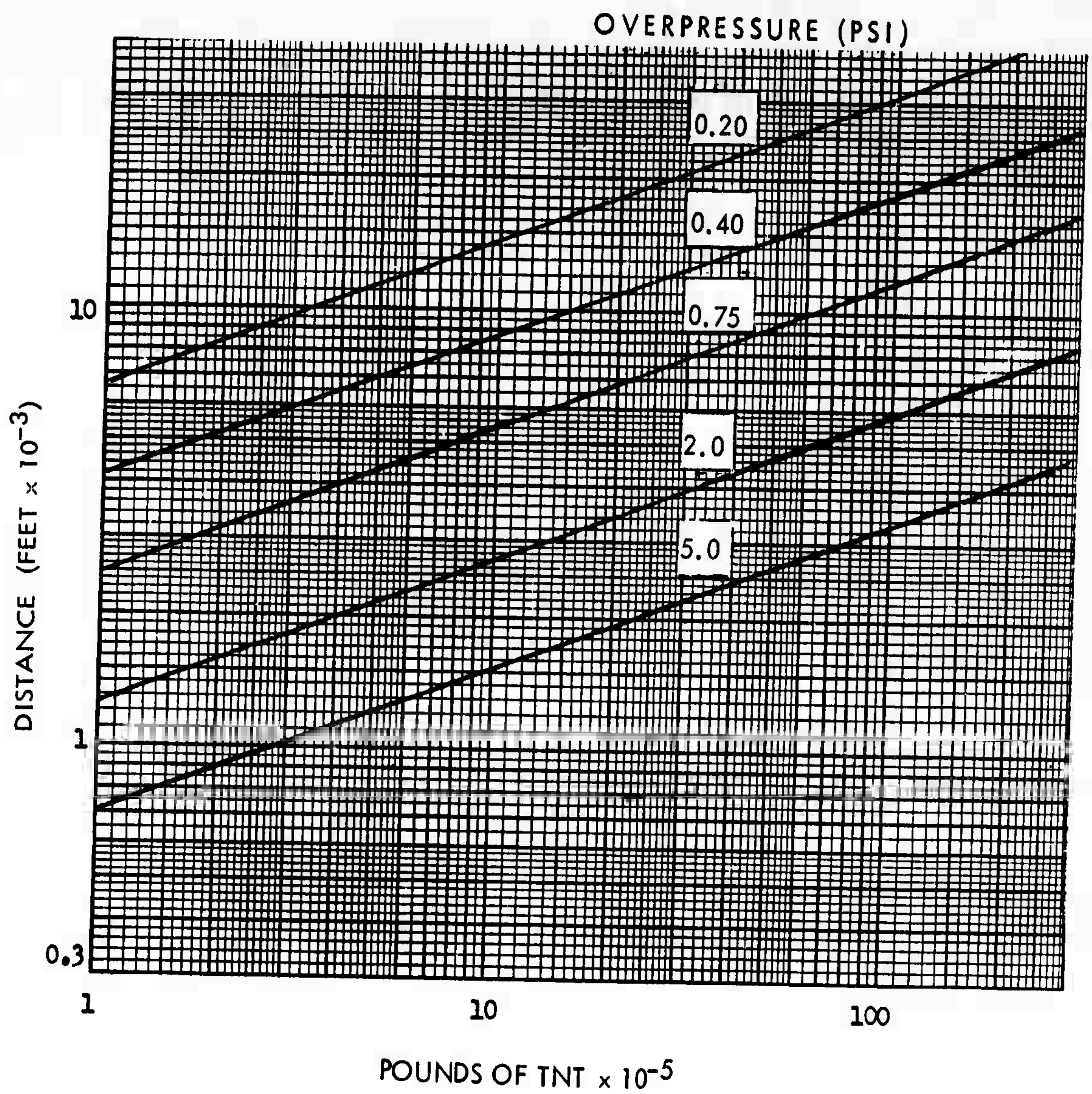


FIGURE 4-3

QUANTITY DISTANCE CURVES FOR VARIOUS OVERPRESSURES

SECTION 5
CONCEPTS

1. GENERAL

This section presents concepts for the handling operations associated with segmented and monolithic motors and boosters from manufacture through launch. These concepts represent the thinking of a number of organizations which have been solicited by AMF for contributions of technical material as part of the industry survey. AMF's conceptual thinking is included as well.

The cooperation of the following companies in supplying information for inclusion in this study is gratefully acknowledged:

1) Cleveland Pneumatic Tool Co., Cleveland, Ohio
2) DeLong Corp., New York City
3) Frederick R. Harris, Inc., New York City
4) Morgan Engineering Co., Alliance, Ohio
5) *New York Shipbuilding Corp., Camden, New Jersey
6) Todd Shipyard Corp., New York City
7) United States Navy, Bureau of Yards & Docks, Washington, D. C.
8) Kaiser Industries Corp., Oakland, California

The concepts presented include both on-pad and ITL approaches.

It is important to note that the concepts shown for either the segmented or unitized motors are, in general, not dependent on motor diameter. It should also be noted that the vehicles pictured in the concepts should be considered representative, since the number of motors in the booster does not, in most cases, affect the over-all handling scheme.

2. SEGMENTED MOTORS AND BOOSTERS

Figure 5-1, page 5-13 is a pictorial representation of typical handling operations associated with segmented motors from the manufacturing facility through launch. Their sequence is as follows:

1) Transportation and Loading Segments.
2) Segment Storage.
3) Inspection.
4) Motor and Booster Assembly.

Motor manufacturing operations are beyond the scope of this effort and will be discussed in this report only where they are similar to procedures occurring at the launch site.

a. Transportation and Loading of Segments.

The transportation sequences outlined below apply primarily to launch operations occurring at the Atlantic Missile Range (AMR). The peculiar geographic location of AMR (typical of low coastal topography), favors the use of barges since canals are easily constructed. Causeways capable of carrying heavy loads are difficult to build in view of the low bearing capacities of the local soil. For the purpose of this study, air transportation is considered an emergency transportation mode only.

Study of the transportation problem has shown that the only feasible methods and combinations are:

1) Rail Car - Barge.
2) Truck - Rail Car - Barge.
3) Truck - Barge.
4) Truck - Rail Car - Rail Car on Barge.
5) Rail Car - Rail Car on Barge.
6) Barge.

NOTE: If plans of constructing a railroad directly to Cape Canaveral should be carried out, an additional mode which encompasses rail transportation would become more feasible.

Figure 5-2, page 5-14 presents methods for the loading of motor segments. The mode of transport and the geographical location of the point of loading (near water, near rail) to a great extent dictate the method of loading.

Railcar loading can take place at the manufacturing facility in a variety of ways. An overhead crane as projected in Figure 5-2A, page 5-14 could be used, or the segment could be transferred directly from its in-plant handling dolly to the railcar by a roller winch system as shown in Figure 5-2B, page 5-14 The roller winch system requires that the railcar bed have a set of rollers similar to that of the dolly.

For intermediate trans-shipment of segments from a truck to a railcar (at a railhead), a portable truck or crawler crane would be used as an alternate to the fixed overhead crane. (See Figure 5-2C, page 5-14).

If trucks were used rather than railcars, loading could be accomplished in a similar manner as shown in Figure 5-3, page 5-15. If the roller dolly is used, the truck must be equipped with a set of rollers.

It should be noted that all concepts shown are applicable to both 120-inch and 156-inch motor segments.

Figures 5-4 and 5-5, pages 5-16 and 5-17 present schemes for loading, transportation and storage of segments on barges. Figure 5-4A, page 5-15 shows the segments being off-loaded from a truck onto a lighter. Since this could occur at a major port, the use of an explosive anchorage is projected. Thereafter, the segment would be carried by the lighter to the larger barge waiting at the explosive anchorage. This method is also applicable when off-loading from a rail car to a lighter at the dock.

Upon arrival of the barge at the launch complex, there are two possible methods of unloading:

1) Unloading at an explosive anchorage (far from the launch facility).

2) Unloading directly at the launch facility harbor.

The factor which determines where the unloading is to occur is a function of the quantity-distance criteria. (See Section 4, page 4-3). Figure 5-4B, page 5-16 shows unloading of segments from the barge to lighter at an explosive anchorage. The quantity of segments to be transported (on the lighter) to the launch facility unloading area is a function of the TNT equivalent of each segment. If it is possible to unload the transport barge directly at the launch facility harbor, an overhead crane could be used to place the segments onto handling dollies.

A particular advantage of barge transportation is the possibility of utilizing the transport barge as a storage facility. This would obviate the need for land-based storage facilities. However, adequate protection would have to be provided in the event of storms. Where lengthy storage is contemplated, tradeoff studies are required to ascertain whether tying up a number of barges for storage purposes would be economical.

Another method of transport currently being considered is the loading of segments from railcars directly onto barges. (See Figures 5-5, page 5-17 Such a rail system would eliminate off-loading facilities (heavy cranes) both at the starting point and at the final destination. This advantage is partially negated by the fact that trackage must be provided at both points. The ultimate answer to the feasibility of such systems must await a detailed study which includes trading off the cost of numbers of railcars tied up vs. projected cost of loading equipment and trackage. It is feasible to utilize the railcars as storage facilities. However, this again creates problems of additional tie up of rolling stock.

Todd Shipyard Corporation of New York has supplied information on another method of barge transport (see Figure 5-6, page 5-18).

This method of transport is feasible when considering a manufacturing facility which uses small barges for in-plant transfer of segments. The dimensions of the small barge shown in Figure 5-6B, page 5-18 are 54 x 30 x 10 feet. They will be moved from station to station in the plant by a small shuttle tug (Figure 5-6C, page 5-18) which can be run by a motor boat operator and a deck hand. These small barges will be compartmented for strength and stability and will have a simple ballasting system to sink the barge to a firm base while various in-plant operations are performed. In addition to the barges and shuttle tug, a bow section would be required for integrated inland waterway tow work. This unit would carry a 30 KW diesel generator to supply power to the environmental control containers shown. The approximate costs, as supplied by Todd Shipyard Corporation,are as follows:

	Each	Delivery
Individual segment transport barges (minimum of 40)	$48, 500	1st - 3 months 4 per month
18 foot Shuttle Tug	$11,750	3 months

	Each	Delivery
Integrated barge bow section complete with 30 KW generator, fuel tank and 200 feet of portable electrical cable with plug in boxes (minimum of 8 bows)	\$56,725	1st - 6 months last - 9 months
Aluminum covers complete with de-humidification machine, strip heaters and controls (minimum of 40)	\$ 4,725	1st - 3 months 4 per month

For short distance transport along inland waters the method of lashing the barges together is adequate, however, for open water transport, integrated tow leaves something to be desired. Another more desirable method for open water transport has also been projected by Todd in Figure 5-6D, page 5-18. Here the individual barges are floated into a semi-submersible vessel for further transport. Among the vessels that could be considered are the LSD[1], the ARD[2] and the LST[3]. Consideration must be given, however, to the water depth at the launch site. At the Atlantic Missile Range the present draft is 7 feet. The cost of procuring and converting an LST for this application is approximately \$355,000. It could transport four segment barges at a speed of 7 knots. Delivery time would be 9 months.

b. Segment Storage.

A number of schemes are available for land based storage of Segments. (See Figures 5-7 and 5-8, pages 5-19 and 5-20). The storage facility concepts are in most cases dependent upon the type of dollies projected for handling the segments at the launch complex. The facility design is also dependent upon the attitude in which the segment will be stored.

The resolution of horizontal versus vertical storage must await a detailed study of the following trade-off considerations.

1) Vertical storage minimizes the possibility of bond separation with time.

2) Horizontal storage would be advantageous from a facility cost standpoint.

3) Bond separation can be minimized by the use of appropriate supporting mechanisms such as mandrels, air bags, etc.

1 - Landing Ship Drydock
2 - Auxiliary Repair Drydock
3 - Land Ship Tank

The concepts presented are applicable to both the 120 and 156-inch segments. Figure 5-7A, page 5-19 projects an inline storage facility for use with a dolly equipped with a roller winch system. Each storage bay is equipped with a roller conveyor system and tie downs. The segment is winched directly from the dolly. (Additional details of this roller dolly are presented on Page 7-2 of Section 7). Figure 5-7B, page 5-19 projects a partially-buried circular storage facility. The segment is placed in the storage bay by the dolly shown. Roller dollies similar to the one mentioned above can also be utilized at this facility.

A disadvantage of the circular facility is the additional dead area between each of the storage bays. This area results from the circular configuration of the over-all facility. Both concepts include provisions for an environmental control system to keep the segments at the desired temperature and humidity.

Figure 5-8A, page 5-20 projects a circular storage facility using a turntable. In this case the segments are stored on their respective dollies. The system projected uses a rail type dolly which is placed on the turntable by a prime mover. The turntable is then indexed to the proper position and the rail dolly winched into the storage bay.

Figure 5-8B, page 5-20, proposed jointly by American Machine & Foundry Company and Thiokol Chemical Corporation to the Air Force, projects a storage facility for use with a Thiokol concepted dolly system. The segment is winched from the trucks to the storage facility turntable via the track system. The turntable is then indexed and the segment winched into its respective storage bay. The indexing operation requires positive positioning of the two trucks. Additional details on the Thiokol dolly can be found on Page 7- of Section 7.

c. Inspection.

For the inspection of solid motor segments, different methods of handling are required if local transportation of the segments is in the horizontal attitude. Figure 5-9A, page 5-21 shows the 120-inch segment on the inspection platform. The segment is placed on the platform with the aid of a roller dolly. In this concept, the platform must be equipped with rollers similar to those on the dolly. In addition to the rollers, the dolly is equipped with a winch and stabilizing jacks for use during the transfer operation. The pallet, which serves as the segment base, is an integral part of the shipping container. Removal of the bottom protective cover from the base plate (accomplished from the Elevator Platform Cage) exposes the ends and insides of the

grain for inspection. Mobile platforms would be provided for access to the outside of the segment. Since the platform is on a turntable, it may be feasible to use it as a mount during radiographic and ultrasonic inspection. If it is not possible to inspect the grain with the internal ring and base plate in place, the segment could be placed on the platform with the aid of a 50 ton overhead crane rather than the roller system. The platform would have to be equipped with a special adapter that would mate with the segment joint. For inspecting larger segments, the only difference would be in the method used to place the segment on the stand. Figure 5-9B, page 5-21 projects the use of two overhead cranes to place the segment on the stand. One crane would have to support the total segment weight, the other only half the segment weight. An alternate to this concept could make use of a breakover stand. This would require trunnions (possibly jack-mounted) at the end of the segment. The rotating operation would then require only one crane capable of handling the entire segment weight. The type of inspection platform projected in this concept is similar in operation to that projected for the 120-inch segment.

It is also possible to utilize the roller dolly projected in Figure 7-3, page 7-7 of Section 7 as the inspection stand by providing capabilities for rotating the segment about its axis. The combined capability illustrates the type of multi-purpose equipment which is so desirable for solid propellant motor AGE.

d. Booster Assembly.

(1) Land Based.

Booster assembly for land based launch complexes is accomplished either on the pad or off the pad. Segmented boosters can be handled by either system. Figure 5-10, page 5-22 shows the booster being assembled on the launch pad by the conventional gantry. Overhead cranes of 250 ton capacity are easily obtainable for this method of booster assembly. The gantry is also used in the assembling of upper stages to the booster. Figure 5-11, page 5-23 shows the assembly of individual solid motors off the pad at a solid assembly building. The motor in this case is being assembled on a transporter. This transporter, shown in more detail in Figure 5-12A, page 5-24 was concepted by AMF for the 624A Program. It consists of a platform structure, motor support system, rail wheel system, positioning system and tie down system.

For the 624A vehicle, the platform would be designed to support the motor while exposed to 40 knot winds (with 60 knot gusts) while moving or at the pad, or 110 knot winds while stored in a Vertical Storage Facility. The platform

structure would be approximately 28 feet by 30 feet. A wheel spacing of 20 feet will provide a stability factor of more than 2 under the above wind conditions.

The motor support structure on the platform, as concepted, is in two sections which pivot away from either side of the missile. The structure consists of tubular support members which meet the structural and stiffness requirements during launch. Hold-down mechanisms, capable of restraining the missile against full thrust would be provided, if required. Flame shielding is provided to minimize refurbishing after launch. Platform mobility is obtained with eight railroad-type wheels. Motive power will be supplied by tractor.

Vertical adjustment at the pad is accomplished with four jacks, one at each corner of the transporter. The jack loads are transmitted to ball bearing thrust plates on the pad foundation. Horizontal adjustment is provided by jacks mounted along the periphery of the transporter platform. Final positioning is obtained by the use of the horizontal wedge system shown.

When considering a vehicle such as the Air Force's 624A, the solid motors, can be mated to the remainder of the vehicle either at the launch pad or at an intermediate station. The first method would require that the solid motors on their transporters be brought directly to the launch pad for mating to the core. The second method could be accomplished as in Figure 5-13, page 5-25 where the solid motors on their transporters are mated to the remainder of the vehicle on the larger transporter. If storage of individual motors is required, they can be stored on the individual transporters as shown in Figure 5-12B, page 5-24. In this case, the motors would be environmentally protected against external conditions by the environmental control system shown. (Additional details on the environmental system can be found on Page 7-3 of Section 7.

Use of individual transporters for vehicles other than those applicable to system 624A can also be projected. Figure 5-41, page 5-74 (discussed toward the end of this section) projects a system using individual transporters for unitized motors. This system is also applicable to assembled segmented motors. Other concepts discussed later in this section (see Figures 5-35 and 5-43, pages 5-69 and 5-76) are also applicable to segmented boosters. Figure 5-43, page 5-76 in particular illustrates an ITL system to which the segmented booster could be assembled off the pad on a booster transporter and transported to the pad for mating to the remainder of the vehicle.

(2) Off-Shore.

In addition to the land based concepts for launch complexes presented above, consideration has also been given to off-shore complexes. Off-shore concepts are somewhat de-emphasized in the minds of facility planners at the present time since recent land purchases in the AMR area appear to suffice for foreseeable real estate requirements. However, as we approach super and post NOVA type vehicle development, this picture may change. A general comparison of on-shore facilities versus off-shore facilities follows:

	ON SHORE	OFF-SHORE
Cost	Construction costs much lower than off-shore. Costs must reflect purchase of real estate by hydraulic filling methods (inclusive of appropriate piling).	High cost of construction resulting from required specialized techniques of underbreakwaters, logistics problems, marine insurance, etc.
Accessibility	Where truck or rail transportation of segments is considered, accessibility is better than off-shore. Accessibility to personnel is no problem.	Where barge or ship transportation of segments is considered, accessibility to an off-shore launch complex is superior to land based complexes. Accessibility to personnel working on the launch stand is poor. This applies also to components which are transported by railroad or truck. Personnel causeways, barge or helicopter transportation must be considered.
Working Conditions for Personnel	Favorable. Inclement weather does not create as adverse condition as it does for off-shore facilities. Better emergency egress potential.	Unfavorable in light of increased discomfort during inclement weather conditions. Expense of construction requires economizing of space with resulting small personnel quarters. Evacuation of pad prior to launch is cumbersome.

Two basic concepts for on-pad assembly at an off-shore complex are presented in Figure 5-14, page 5-26. Concept A is a submerged caisson approach and Concept B a high gantry approach. The high gantry approach is an extension of conventional land-based techniques. A service tower or gantry capable of erecting the entire vehicle is provided at the pad. The vehicle would be assembled by bringing components to the launch stand and assembling them by means of cranes suspended from the gantry. The gantry would be retracted prior to launch.

The submerged caisson approach consists of a silo, the upper end of which is approximately even with the grade in the case of a land based facility, or slightly above the water level in case of an off-shore facility. The silo contains a launch platform which is capable of moving vertically along its length.

In preparation for launch, the vehicle would be raised on the platform to its highest position. During the elevation operation, the platform base is closed. Upon reaching ground level, the platform is locked into position and its base opened to allow passage of exhaust gases. During vehicle assembly, the platform would be lowered as required to facilitate assembly of successive components and stages.

COMPARISON OF HIGH GANTRY AND CAISSON APPROACHES

Parameter	High Gantry	Caisson
Cost	High. Necessity of designing gantry against hurricane winds requires very heavy and cumbersome construction.	High. Off-shore caisson construction is expensive. Land based underground silo requires deep excavation (300 feet) with attendant costs.
Protection of Vehicle from Hurricanes	Vehicle could be tied to gantry during hurricanes. This requires careful analysis of gantry and vehicle stiffness characteristics.	Provides excellent protection by permitting lowering of entire vehicle.
Development Risk	Relatively low. The loads on the gantry can be calculated from known wind forces.	Relatively low. The caisson concept has been applied previously in a more complicated form (Titan Silo Lift).

Parameter	High Gantry	Caisson
Reliability of Operation	Good but somewhat complicated as a result of height and exposure to bad weather conditions.	Lower than gantry concept in view of necessity of machinery for raising and lowering entire vehicle.

Figure 5-15, page 5-27 is a concept for a semi off-shore ITL system. Segments would arrive from the manufacturing facility via barge and be stored on the barge until needed. The segments would then be transferred to the assembly facility via a small barge as they are required. Upon completion of individual motors at the assembly facility, they would be transported by barge to the booster assembly facility for clustering into a booster. The booster is transported to the launch pad by a special transfer barge. The launch pad can be either silo or gantry type. The silo type is illustrated. Liquid stages are then brought to the launch pad from a shore-based assembly facility by a special liquid stage transfer barge which incorporates a hoist capable of lifting the assembly liquid stages to the top of the solid booster.

FOR DISCUSSION REFER TO PAGE 5-3

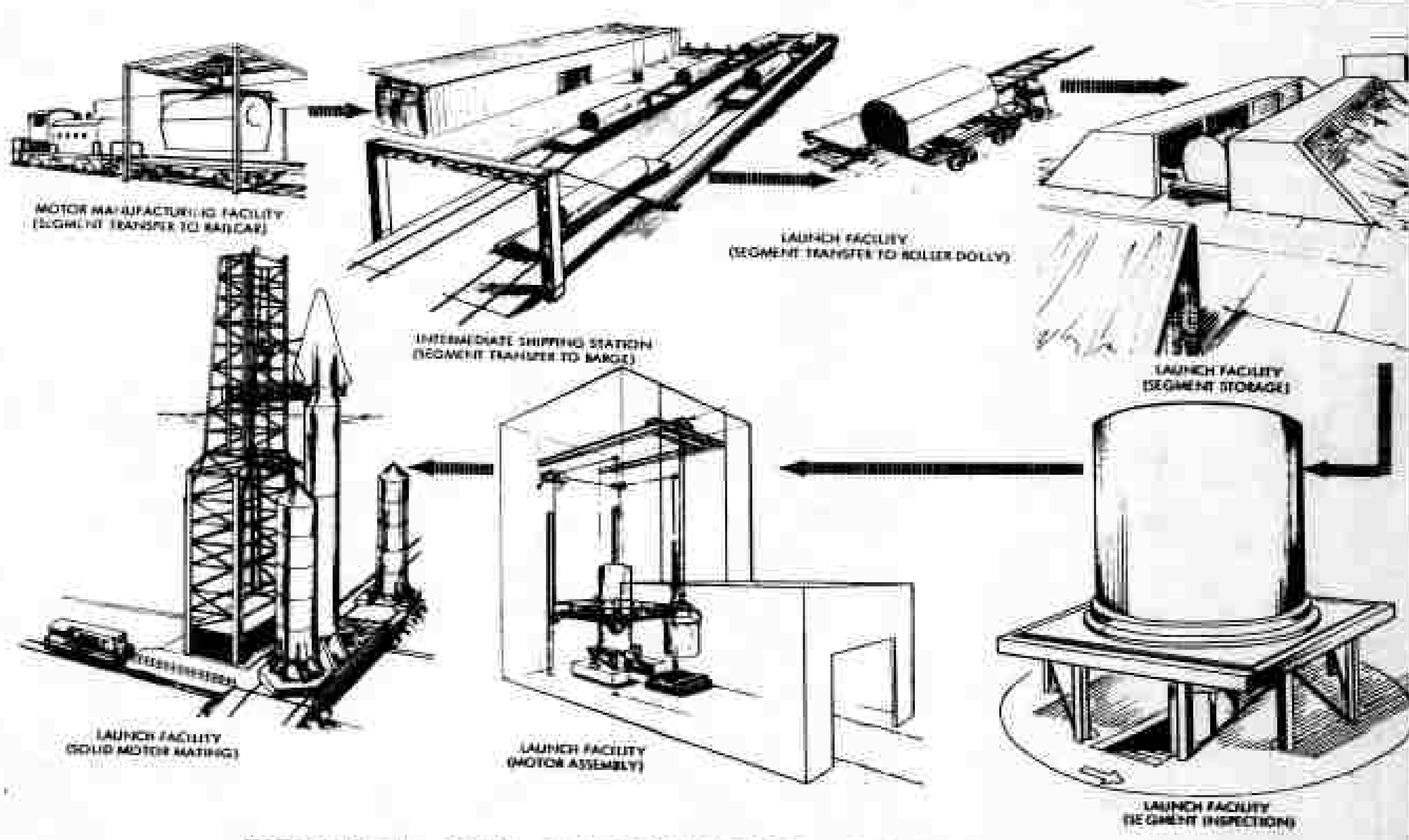
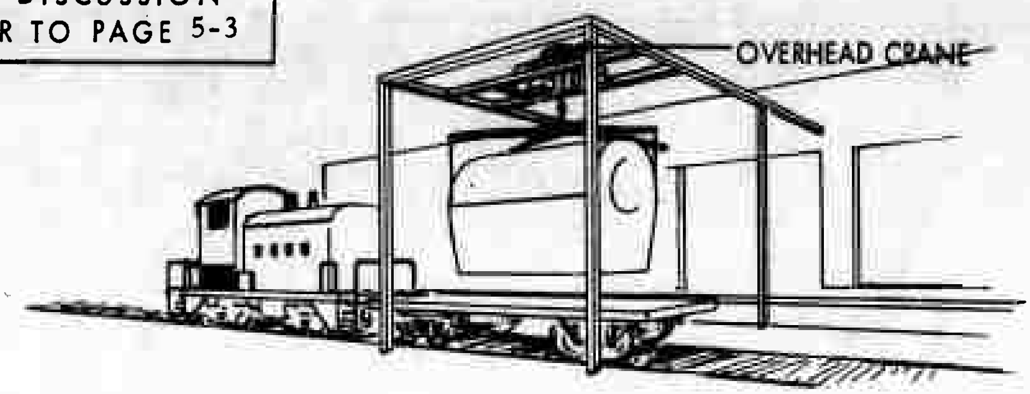
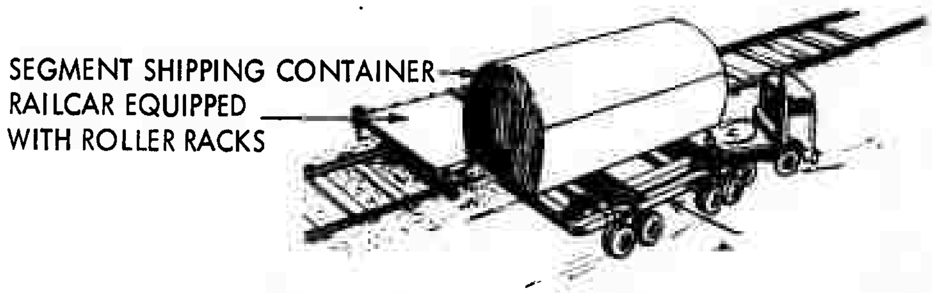


FIGURE 5-1. OVER-ALL FLOW CHART – SEGMENTED MOTORS

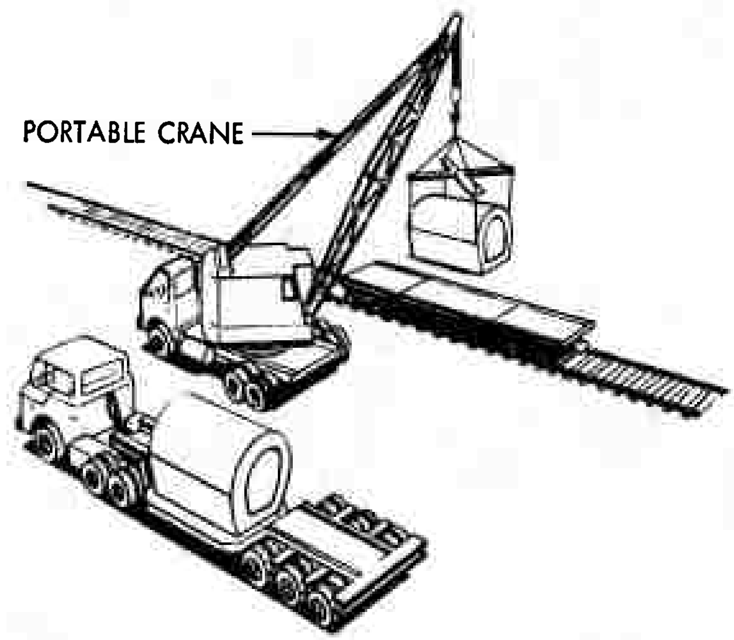
FOR DISCUSSION
REFER TO PAGE 5-3



A. OVERHEAD CRANE TO RAILCAR (AT MANUFACTURING FACILITY SHIPPING STATION)



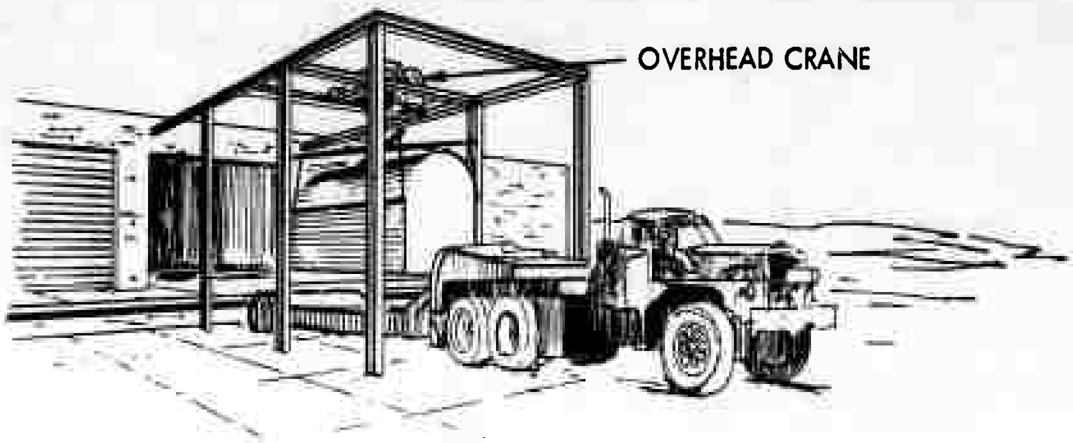
B. ROLLER DOLLY TO RAILCAR (AT MANUFACTURING FACILITY)



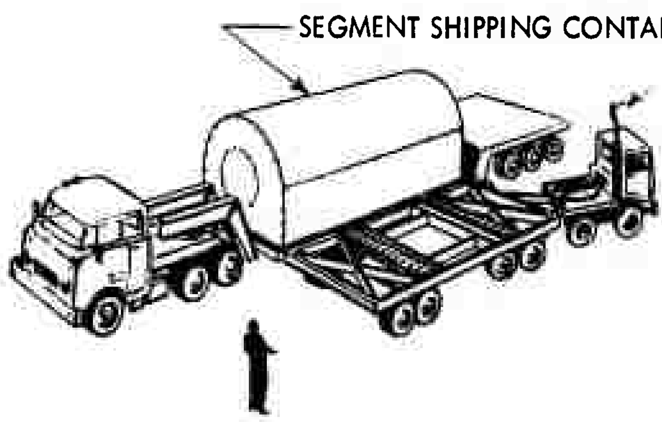
C. TRACTOR TRAILER TO RAILCAR (AT INTERMEDIATE SHIPPING STATION)

FIGURE 5-2
SEGMENT TRANSFER

FOR DISCUSSION REFER TO PAGE 5-4



A. OVERHEAD CRANE TO TRACTOR TRAILER
(AT MANUFACTURING FACILITY SHIPPING STATION)



B. ROLLER DOLLY TO TRACTOR TRAILER (AT MANUFACTURING FACILITY)

FIGURE 5-3
SEGMENT TRANSFER

FOR DISCUSSION REFER TO PAGE 5-4

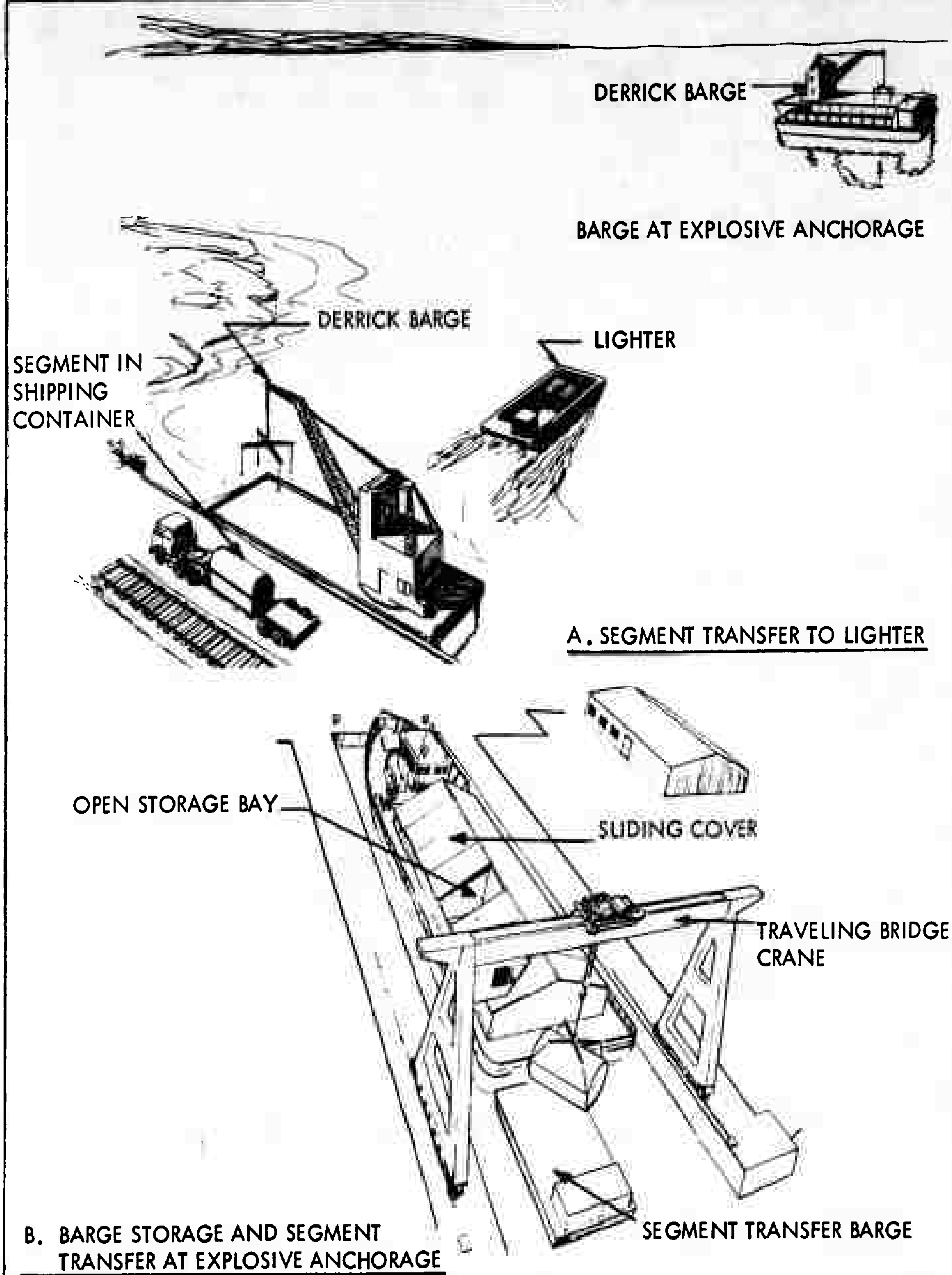


FIGURE 5-4
BARGE LOADING, TRANSPORTATION AND STORAGE

FOR DISCUSSION REFER TO PAGE 5-5

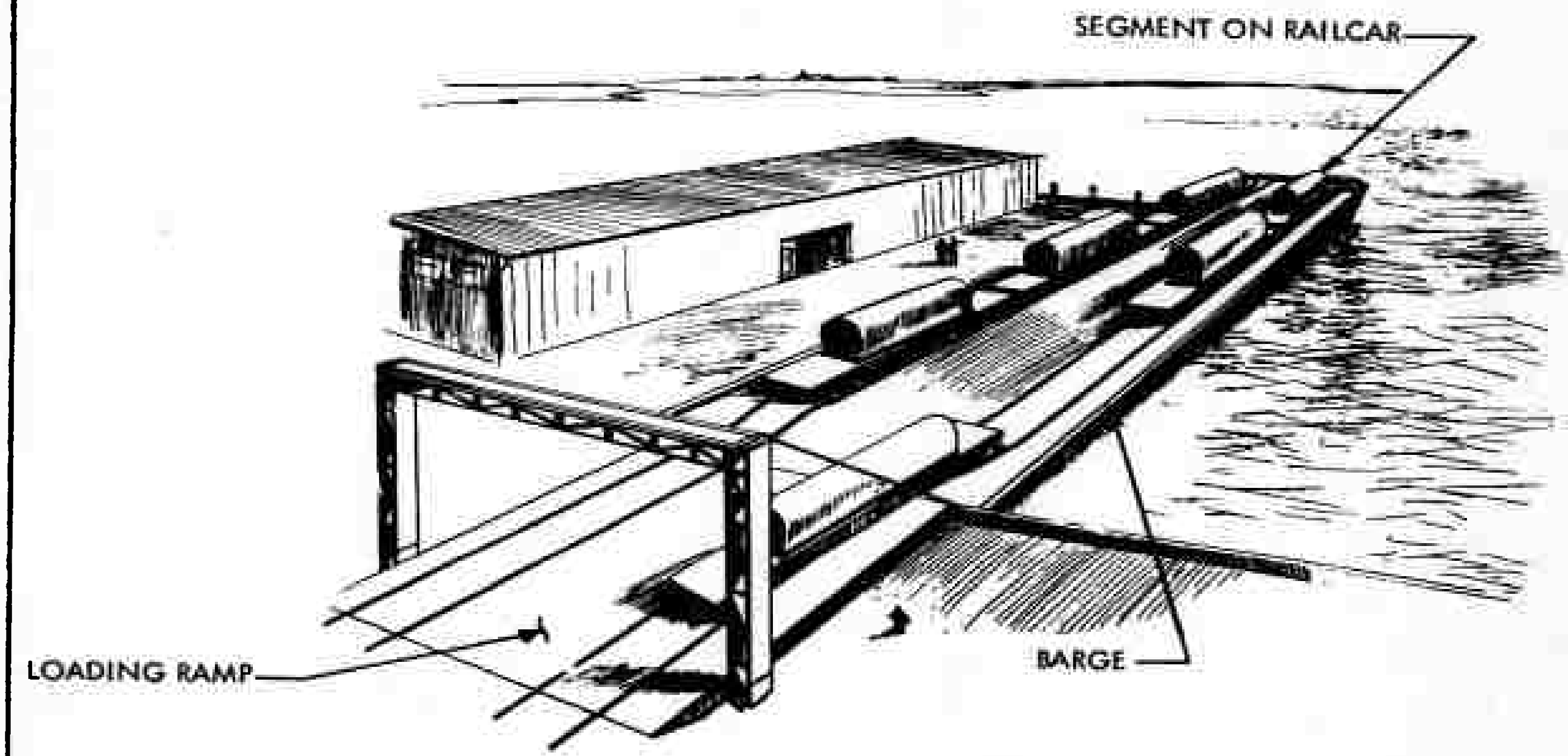
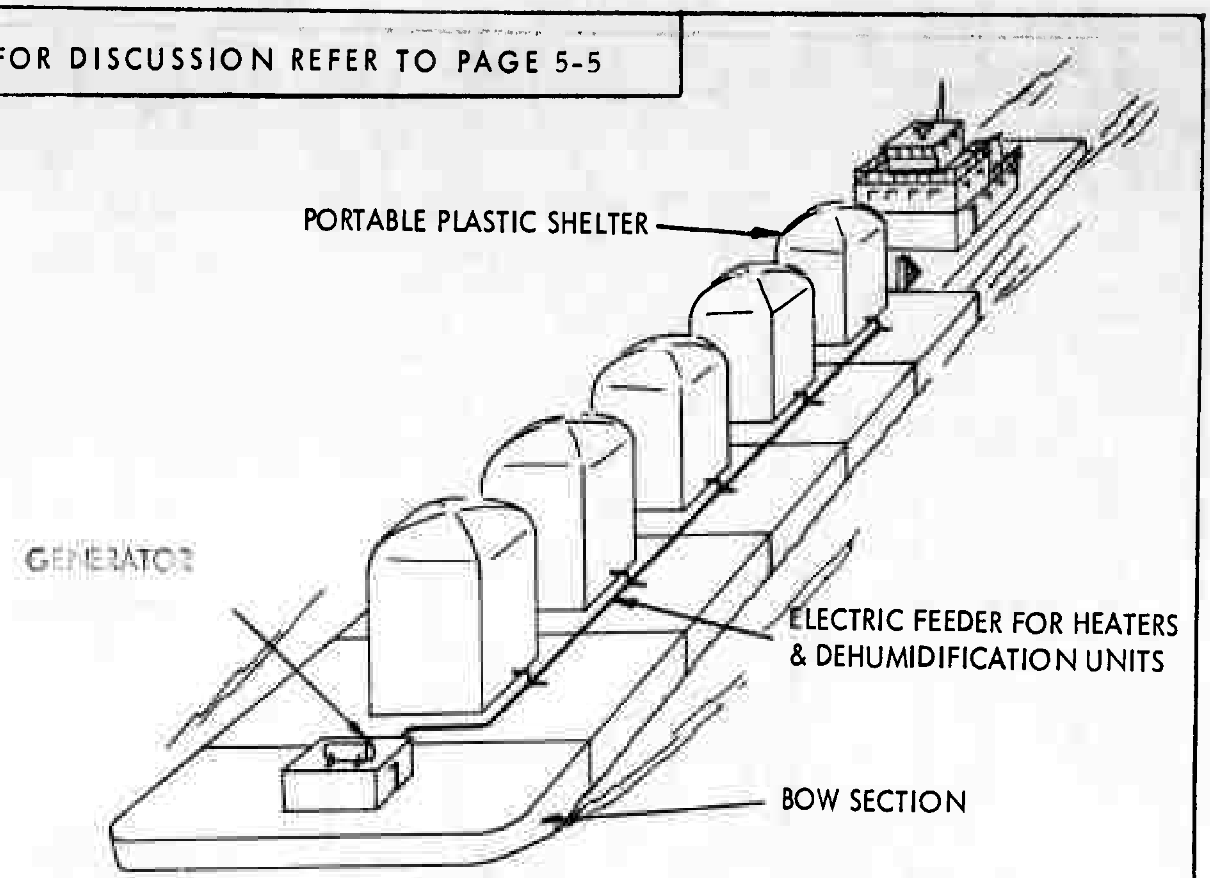
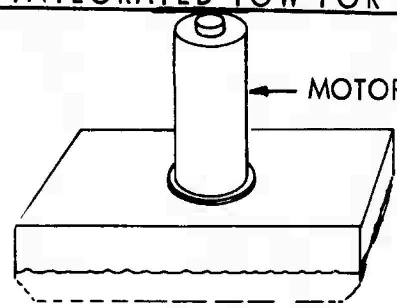


FIGURE 5-5
LOADING OF RAILCARS ONTO BARGES

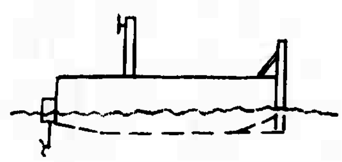
FOR DISCUSSION REFER TO PAGE 5-5



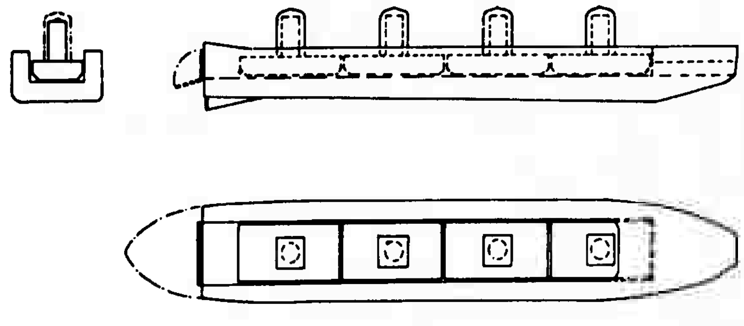
A. INTEGRATED TOW FOR INLAND AND INTRACOASTAL WATERWAYS



B. INDIVIDUAL SEGMENT BARGE



C. SHUTTLE TUG

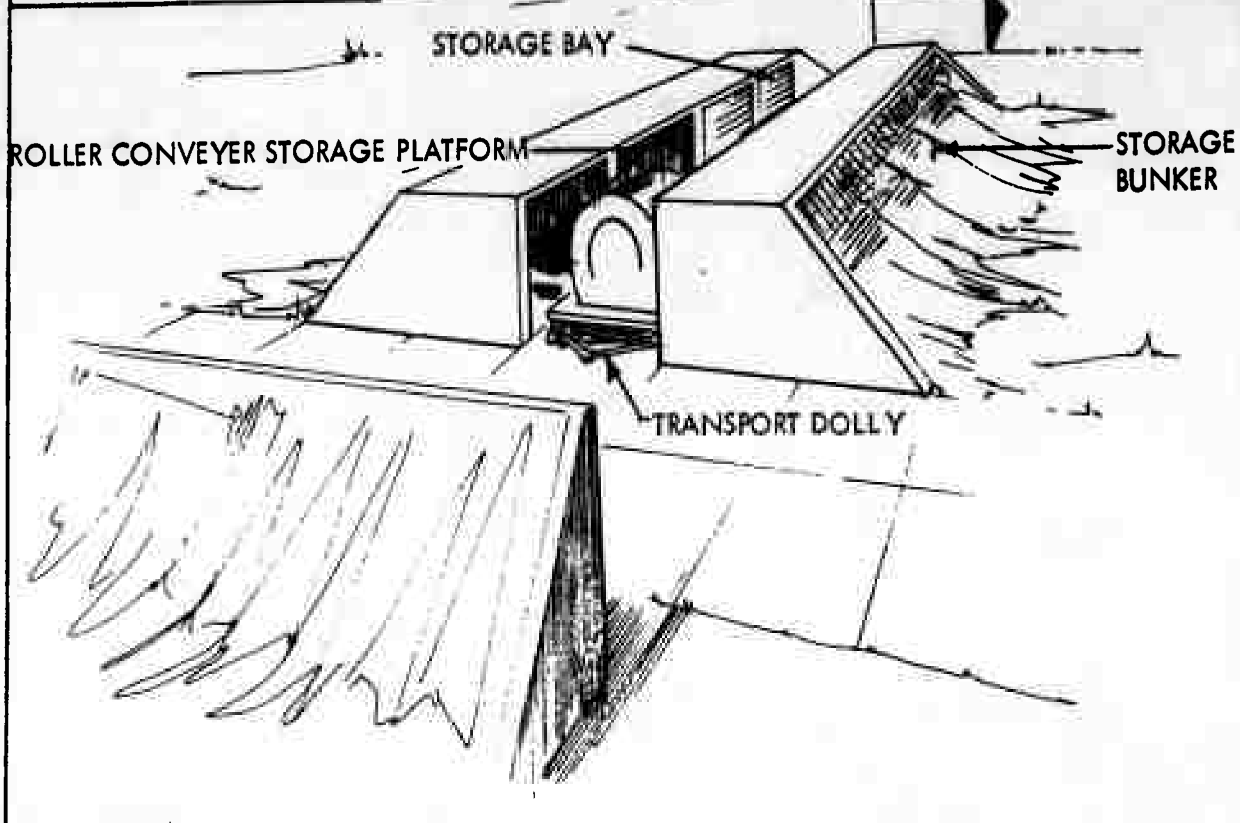


D. INDIVIDUAL BARGES ON CONVERTED LST

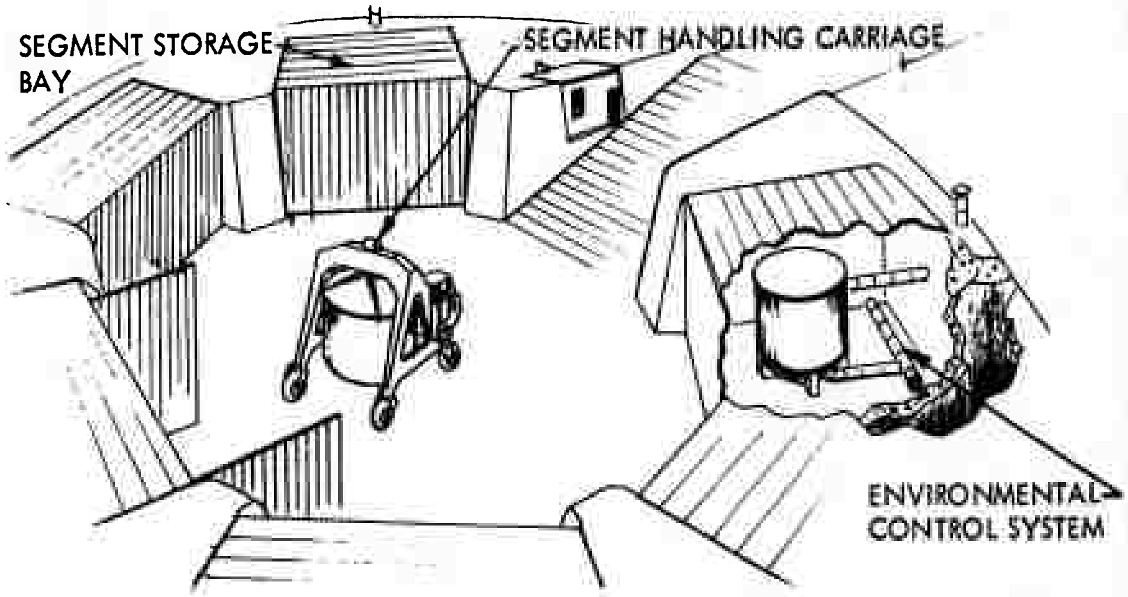
FIGURE 5-6

BARGE LOADING, TRANSPORT AND STORAGE
(SUPPLIED BY TODD SHIPYARDS CORPORATION)

FOR DISCUSSION
REFER TO PAGE 5-7



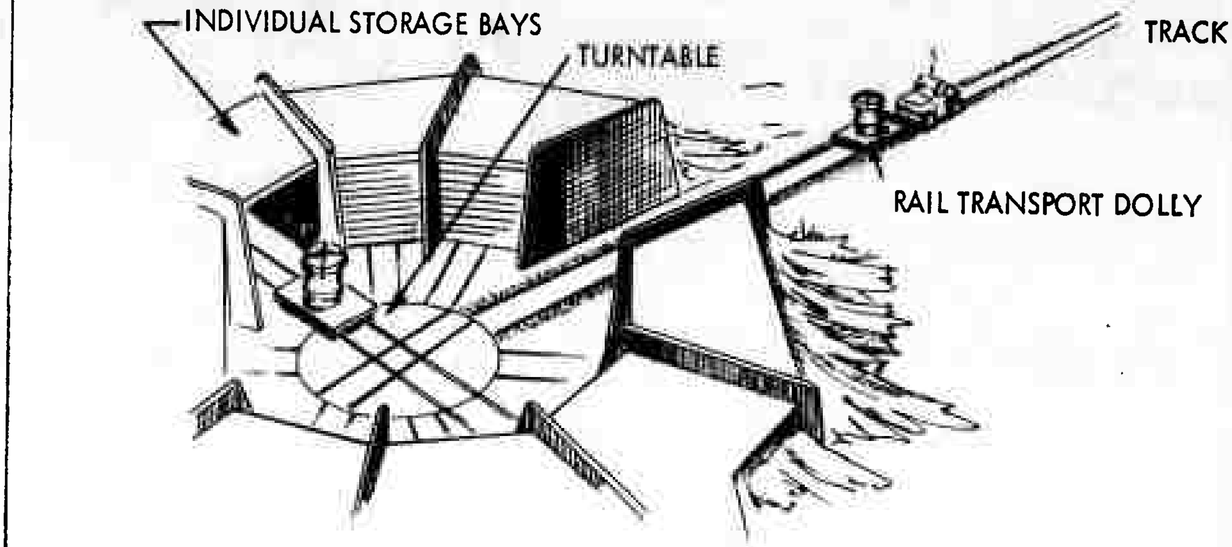
A. IN-LINE STORAGE FACILITY (ROLLER CONVEYER - WINCH SYSTEM)



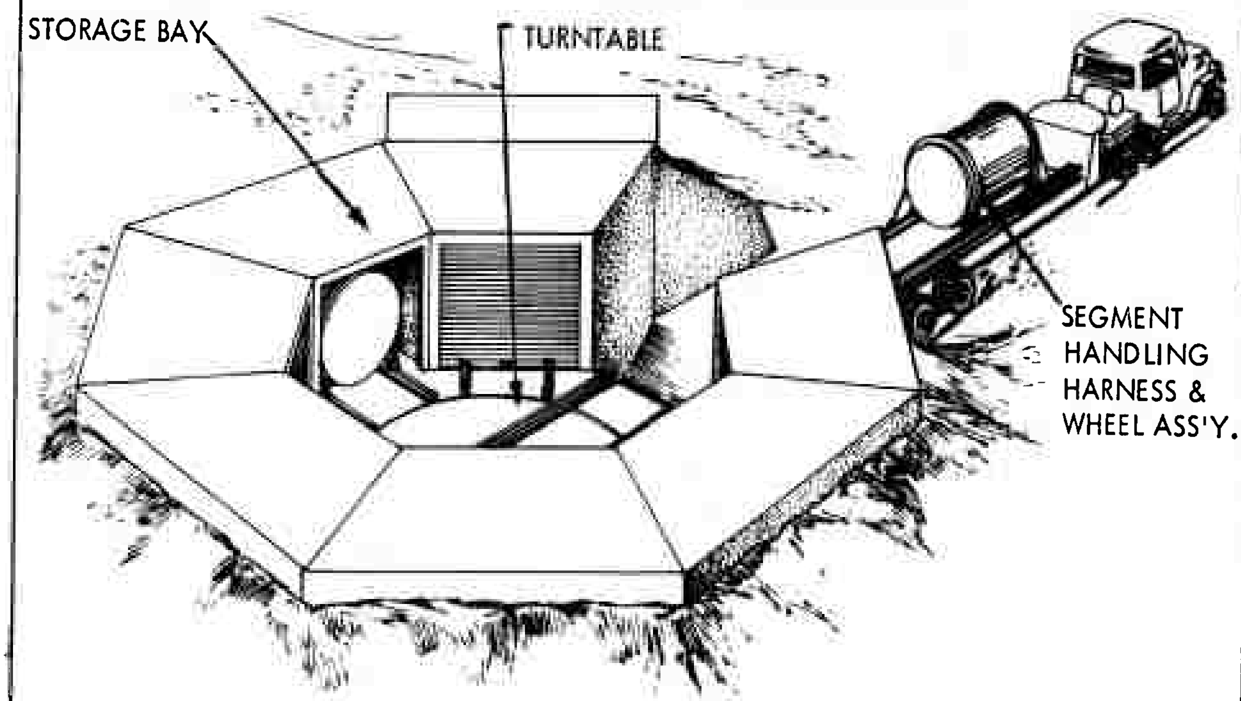
B. BELOW GROUND CIRCULAR STORAGE FACILITY

FIGURE 5-7
SEGMENT STORAGE

FOR DISCUSSION REFER TO PAGE 5-7



A. RAIL DOLLY - TURNTABLE STORAGE FACILITY

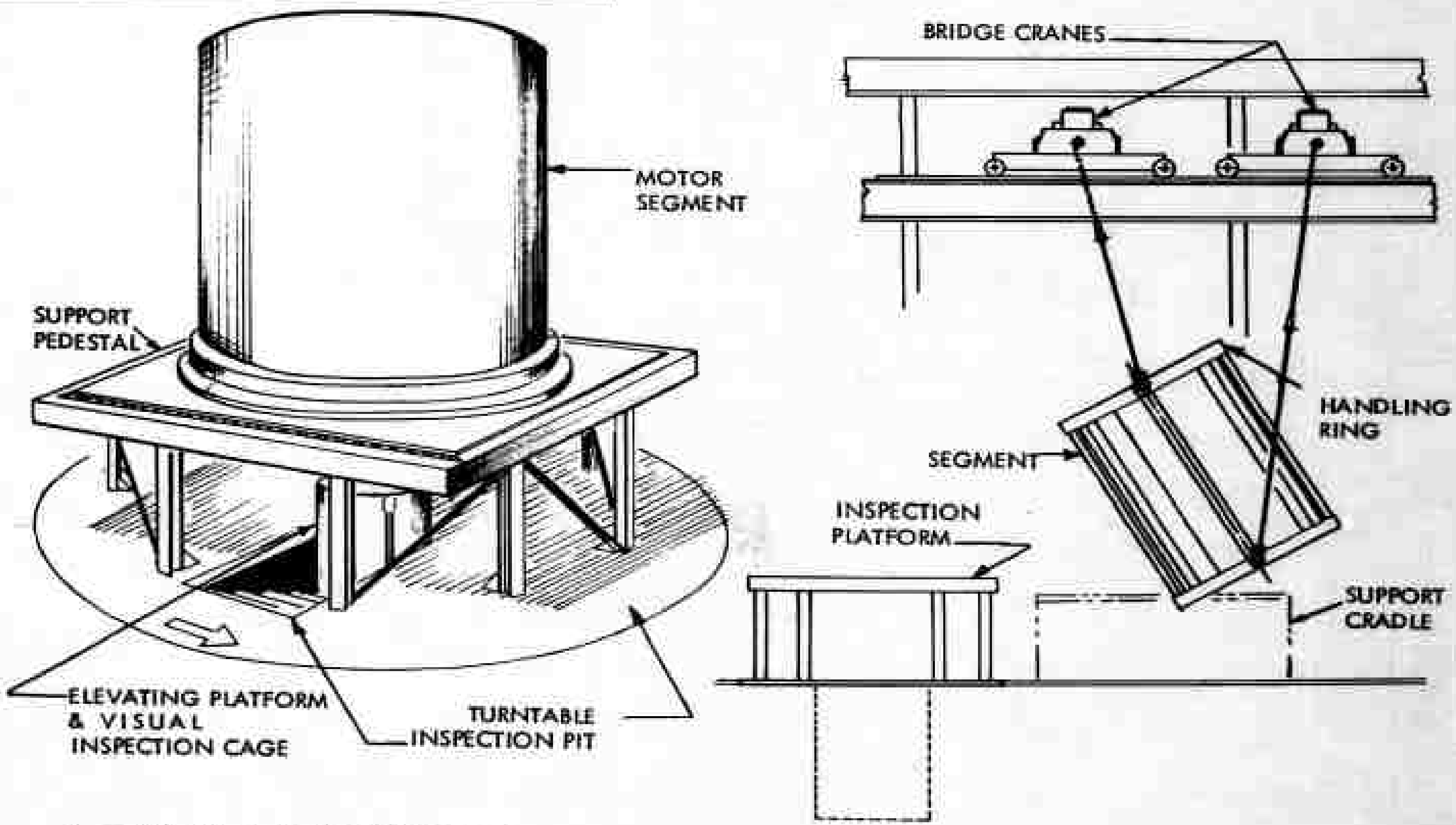


B. BELOW GROUND - TURNTABLE STORAGE FACILITY

FIGURE 5-8

SEGMENT STORAGE

FOR DISCUSSION REFER TO PAGE 5-7



A. TURNTABLE AND VISUAL INSPECTION PLATFORM

B. HORIZONTAL SEGMENT HANDLING

FIGURE 5-9
INSPECTION

FOR DISCUSSION REFER TO PAGE 5-8

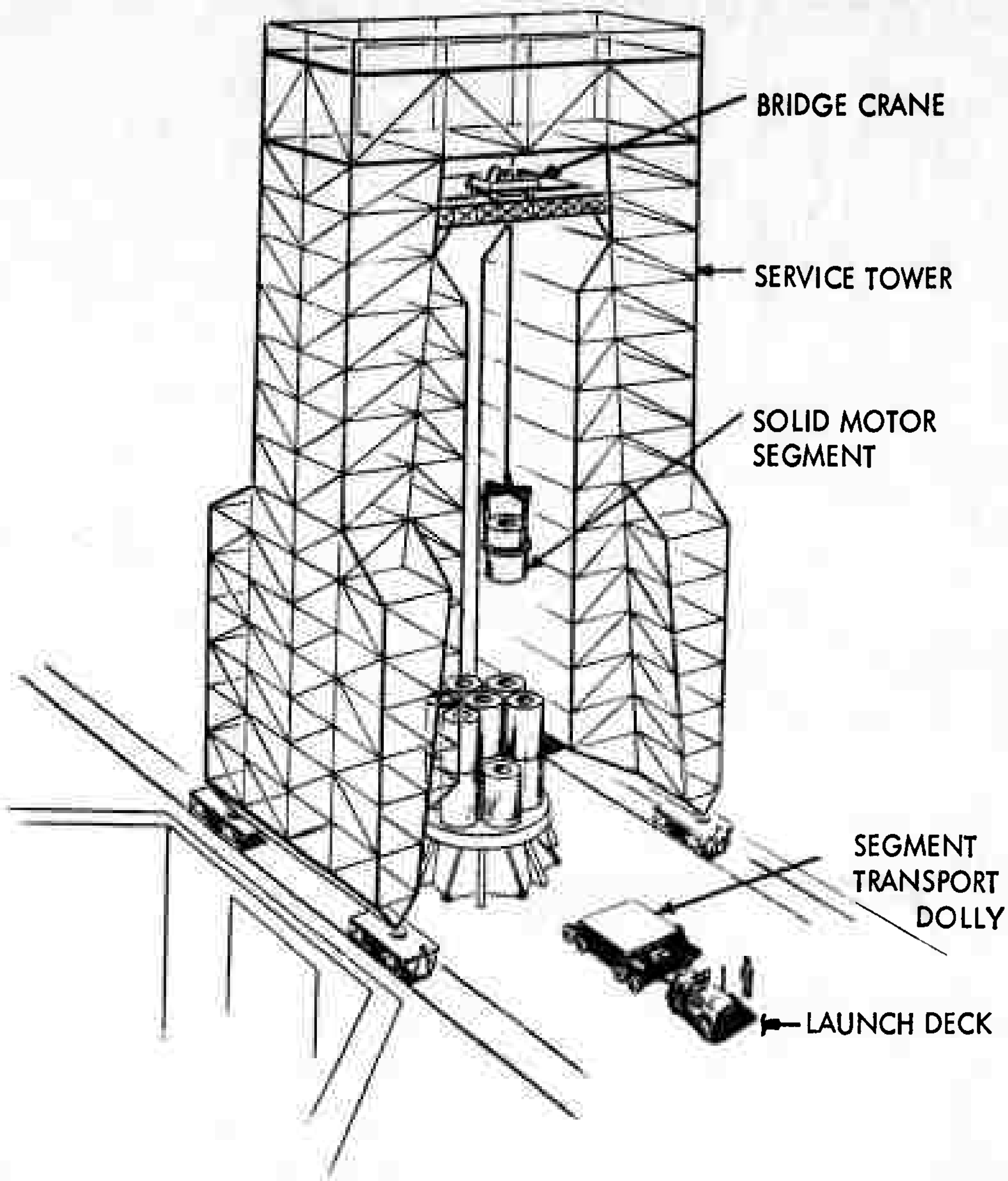


FIGURE 5-10

ON-PAD BOOSTER ASSEMBLY

FOR DISCUSSION REFER TO PAGE 5-8

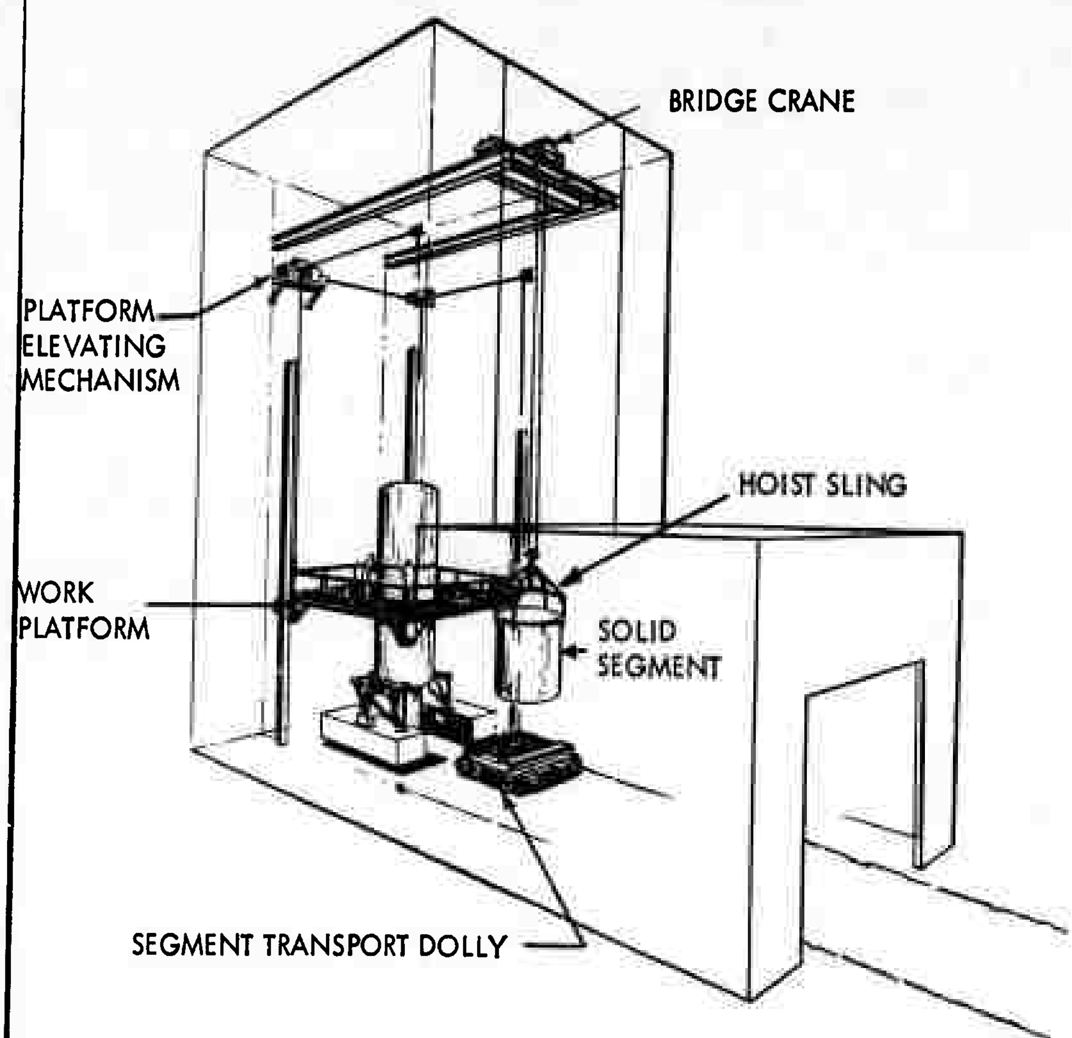


FIGURE 5-11
SOLID MOTOR VERTICAL ASSEMBLY FACILITY

FOR DISCUSSION
REFER TO PAGE 5-8

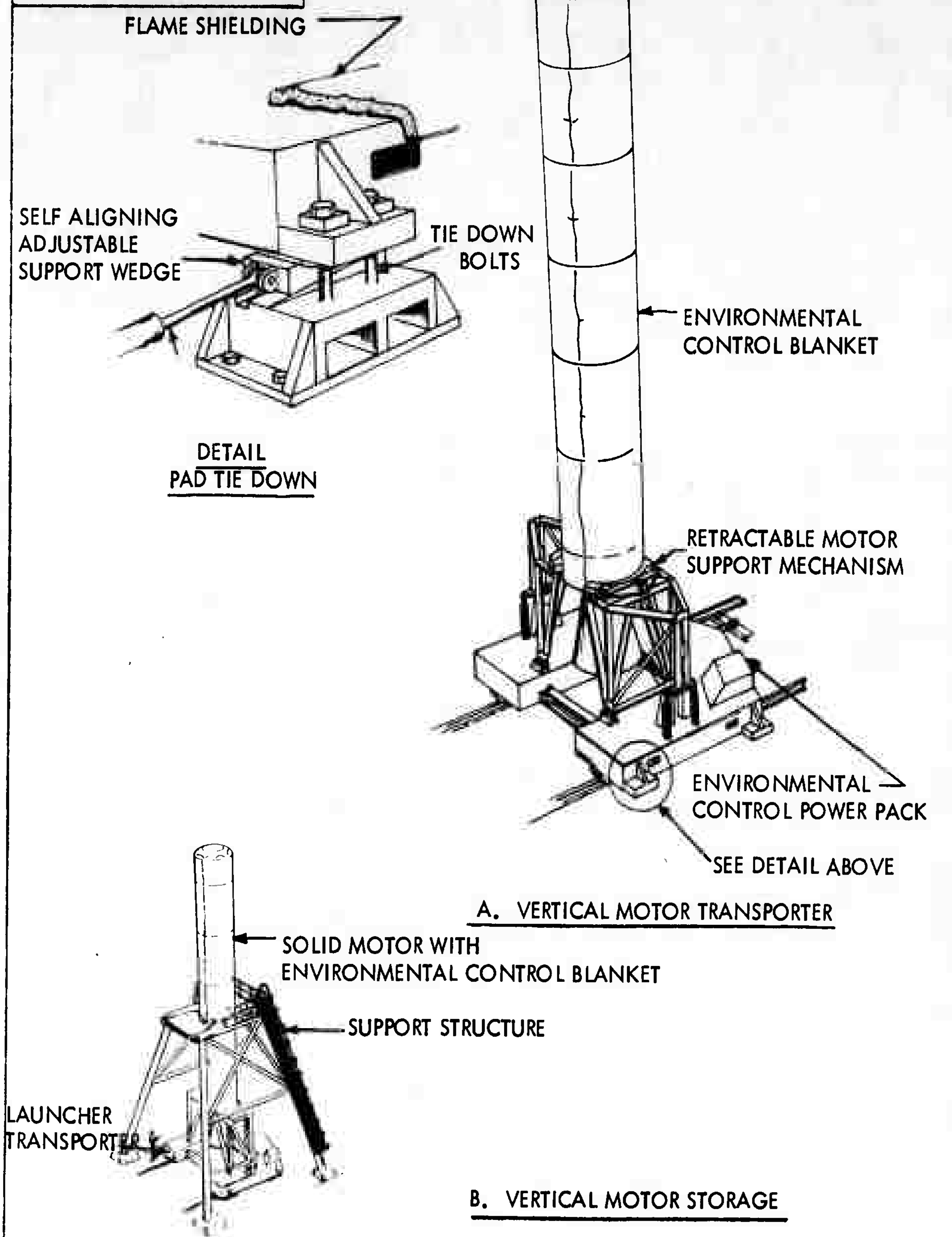


FIGURE 5-12

TRANSPORT AND STORAGE OF SOLID MOTORS

FOR DISCUSSION REFER TO PAGE 5-10

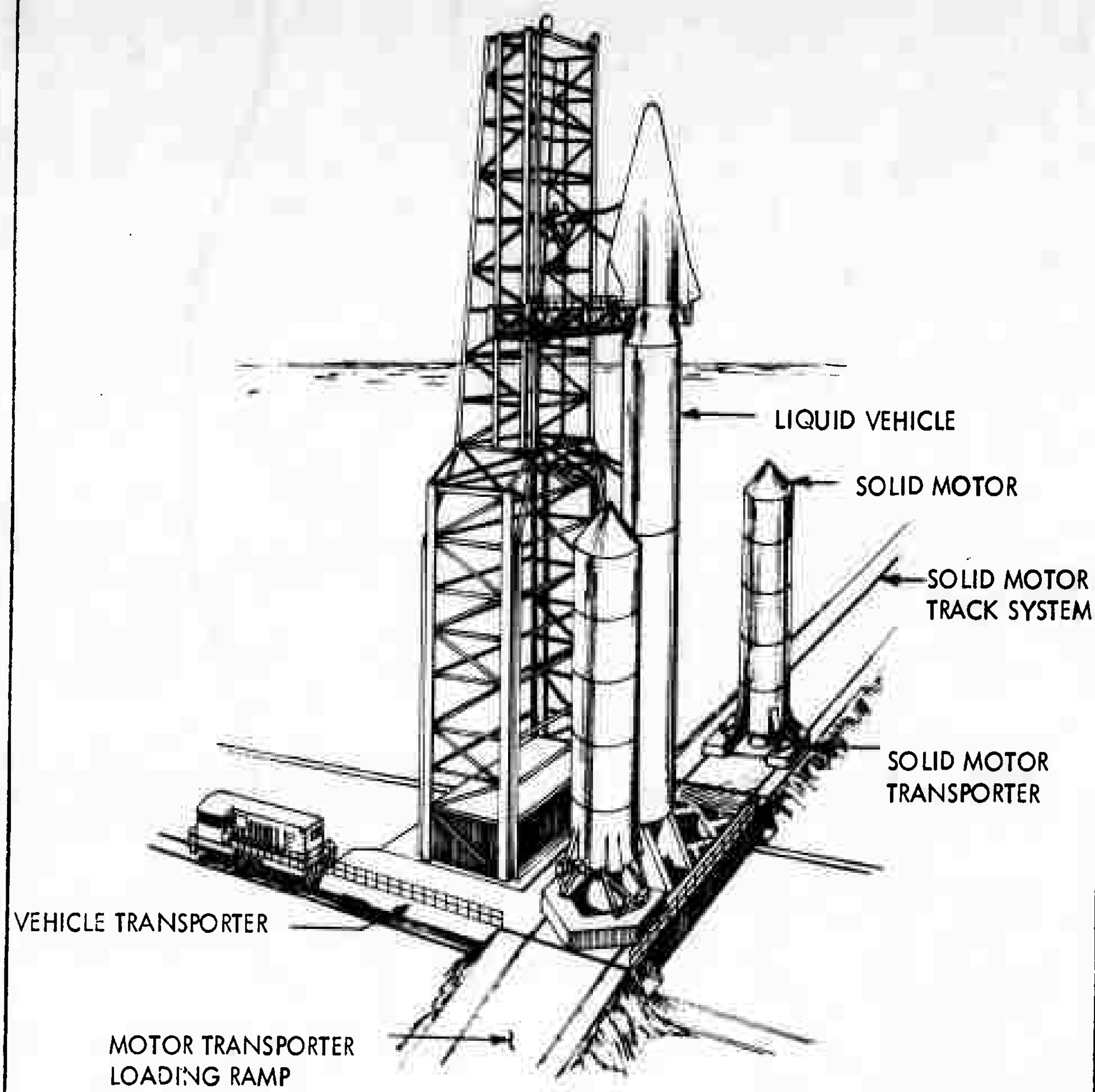


FIGURE 5-13

SOLID MOTOR MATING STATION CONCEPT FOR 624-A SYSTEM

FOR DISCUSSION REFER TO PAGE 5-11

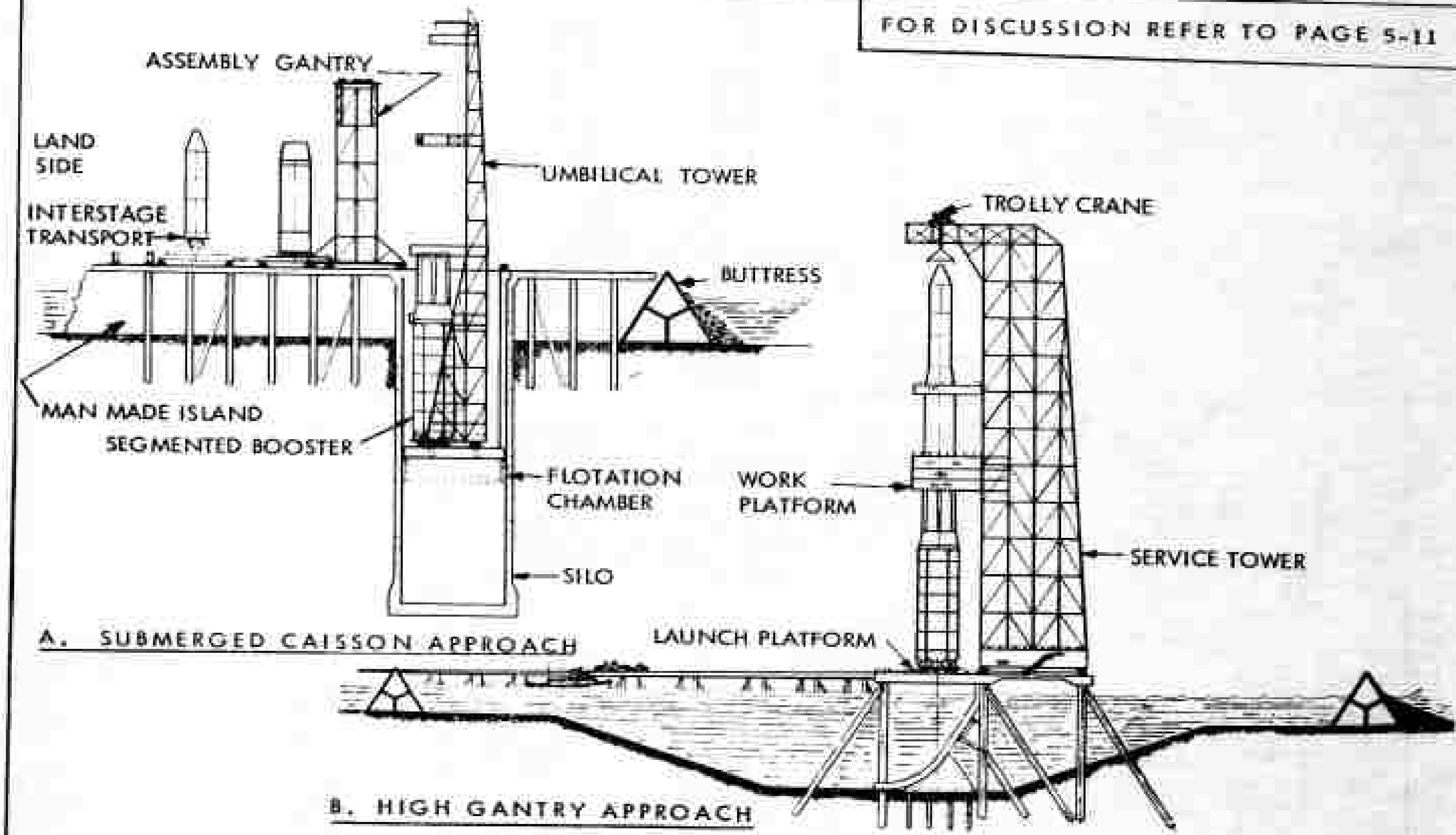


FIGURE 5-14

OFFSHORE LAUNCH PAD CONCEPTS

FOR DISCUSSION REFER TO PAGE 5-12

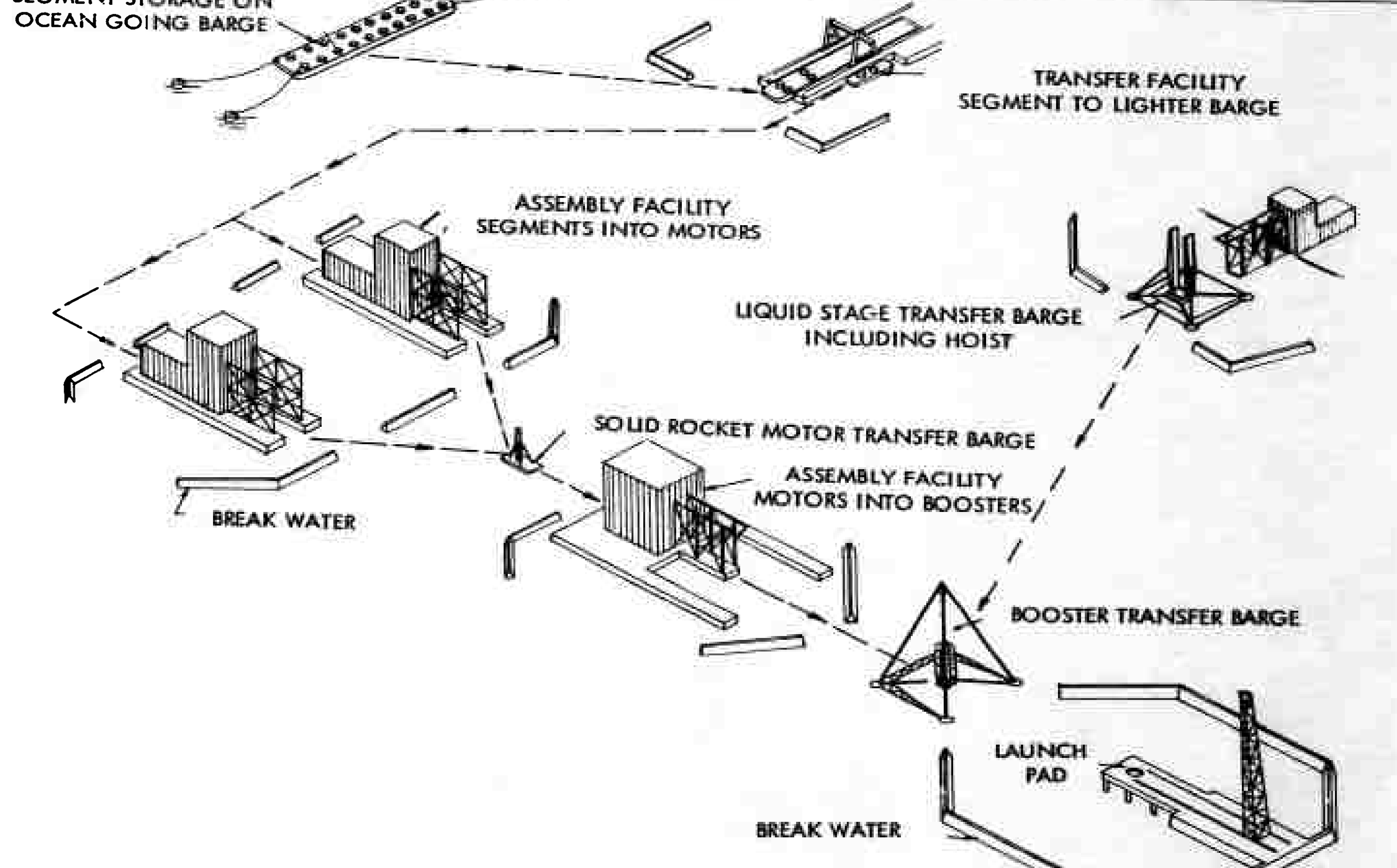


FIGURE 5-15
OFFSHORE LAUNCH SITE-INTEGRATED APPROACH

3. UNITIZED MOTORS AND BOOSTERS

Figure 5-16, page 5-50 shows the operations involved in handling monolithic motors from the case manufacturer through vehicle launch. The concepts presented, along with other concepts, are discussed in greater detail in the remainder of this section.

The operations associated with monolithic motors will be discussed in the following sequence:

1) Empty case, loading and transport.
2) Motor manufacturing and static test.
   a) Dry schemes.
   b) Wet schemes.
3) Transportation and handling of loaded motors.
4) Motor erection.
5) Booster Assembly.

a. Case Loading and Transport.

It is expected that transport of the empty motor cases to the manufacturing facility will be via barge. Although it may be feasible to transport this case over land via special transporter and specially prepared roads, water transportation is preferred since the motor manufacturing facility must be near water to allow barge transport of completely poured motors to the launch site (AMR). The cases can be loaded aboard the barges by overhead crane, by transporter, or by floating them onto a semi-submerged vessel.

Four concepts for case loading and transport are presented.

(1) Kaiser Industries. Figure 5-17, page 5-51.

(a) Description.

Drydock facility for manufacturing of motor cases.

(b) Operation.

1) Flood the drydock and partially fill the case, thus maintaining a positive weight to prevent floatation.

2) Tow barge into dock.

3) Flood barge and sink it.

4) Lower the case to a horizontal position in the drydock.

5) Float the case over the barge.

6) Partially evacuate drydock to initially settle the case onto the barge cradles.

7) Evacuate barge to complete seating operation.

(2) AMF. Figure 5-18A, page 5-52.

(a) Description.

The caisson consists of eight interchangeable center units which are split longitudinally to facilitate removal. The center caisson assembly serves as a strongback. A center trunnion (split) serves as rotating axis. Provisions are incorporated to facilitate rotating of the motor during X-Ray inspection.

(b) Operation.

1) For short distance transport - floated behind powered tug.

2) For long distance transport - floated onto semi-submerged barge.

(c) Budgetary Cost Estimates.

1) One prototype caisson - $1, 300, 000.

2) Thirty sets of harnesses, attachment rings and center caisson assemblies - $550, 000.

3) Aft and Forward closure assemblies - $250, 000 per set.

(3) New York Shipbuilding Corporation. Figure 5-18B, page 5-52.

(a) Description.

Structural Suitcase.

(b) Operation.

Suitcase is placed on barge by winching system.

(4) Todd Shipyard Corporation. Figure 5-19, page 5-53.

(a) Description.

A Case Transporter loaded onto a barge. The scheme is projected for both empty and fueled motor cases (the stability of the scheme with an empty case is questionable).

The major items shown are the barge with loading ramp and the transporter container (transtainer).

Barge dimensions are: Length - 195 ft., width - 50 ft., depth - 13 ft.
Loading Ramp dimensions are: Length - 40 ft., width - 30 ft.
Transtainer dimensions are: Length - 90 ft., width - 24 ft.

(b) Operation.

1) Transport the empty or fueled case to the loading slip by means of the transtainer.

2) Place barge, stern first, in loading slip and ballast it.

3) Lower the ramp and key the ramp track to barge.

4) Pull transtainer onto barge by means of car pullers and secure.

5) Maintain trim of barge by means of ballast system.

b. Motor Manufacturing and Static Test.

The ground rules used for determining the procedures to be used at the manufacturing and static test facility were obtained from requirements set forth by various military and civilian agencies. The basic ground rules for the handling of the 260-inch monolithic motor are that the motor should be cast, cured, and static tested in the same place. The manufacturing techniques currently envisioned for the 260-inch unitized motor are different from those used for the 120-156-inch segmented motors. This difference arises primarily out of the large size and weight associated with the 260-inch unitized motor. Present thinking is that the manufacturing facility will also serve as the static test facility. It is desirable to have this combination facility as close to the launch site as practical.

The projected operation of this facility is as follows:

1) The empty motor case would be brought from the case vendor's facility to the motor manufacturing/static test facility.

2) The case will be erected nozzle-up.

3) After insertion of a suitable mandrel and appropriate liner material, the propellant will be cast and cured.

4) Subsequent to curing and removal of the mandrel, the motor may either be static tested or transferred to the horizontal attitude for transport to the launch site.

The facility required for a test of the destruct system of the 260-inch motor is not shown in any of the motor manufacturing/static test site concepts discussed in this report. This facility will probably test the motor in the horizontal position so that the destruct test can be performed with minimum danger to surrounding facilities. A simple bay with surrounding abutments and cover is contemplated.

Two general schemes are possible for manufacturing and static test (1) dry, and (2) wet. A discussion of both dry and wet manufacturing and static test is presented below. An evaluation of various manufacturing/static test concepts can be found in Section 11.

(1) Dry Schemes.

(a) AMF. (Figure 5-20, page 5-54)

1. Description:

This is a fully above-ground, land-based manufacturing/static test facility. The concept shown utilizes a chain-drive system (concepted by the Jeffrey Co.) which pulls a transporter up a 5% ramp to a height of about 60 feet. The chain drive consists of eight (8) separate drives all synchronized and driving positively on two fixed chain type tracks, one between each pair of rails.

The transporter is capable of spanning the motor case in position on the barge. Raising and lowering of the transporter, necessary in view of the fact that the entire motor is lifted off the barge at six trunnion points, is accomplished by hydraulic jacks which form part of the bogie assemblies. Other methods of moving the transporter up the ramp would include cable drives, self-powered wheels and a prime mover vehicle. Further trade-off studies must be made before the optimum method can be determined.

The facility includes a 50-ton crane which is required for removal of the mandrel, nozzle emplacement and placement of propellant bins. In addition, a personnel elevator is used to provide access to the various locations along the motor.

2. Operation:

1) Unload the motor case from its transport vessel at the docking facility with the aid of the transporter.
2) Pull the transporter up the grade to the top of the ramp with the aid of the chain drive system.
3) Free the forward and aft trunnions and erect the motor case with the aid of the winching system (integral with the transporter).
4) Place the motor on the thrust mounts with the aid of auxiliary jacks for final positioning.
5) Remove the transporter from the area.
6) To remove the loaded motor from the facility, reverse the above procedure.

3. Budgetary Cost Estimates.

Construction Cost	2 million
Mechanical Equipment	2.5 million
Transporter	
Chain Drive	
50 Ton Crane	
Jacking System	
Personnel Elevator	
Propellant Curing System	
Work Platforms	
Door Operating Systems	
Power Supply System	
Total Facility Cost	4.5 million (approximately)

(b) AMF. (Figure 5-21, page 5-55)

1. Description:

This is a Facility very similar to the AMF-concepted facility mentioned above, except that the ramp has been replaced by a partial excavation.

2. Operation:

Same as the facility projected above. (See Page 5-33).

(c) Todd Shipyard Corporation. (Figure 5-22A, page 5-56)

This concept shows the use of the Todd Transtainer (Figure 5-19, page 5-53) integrated into a complete facility. Erection of the Transtainer is accomplished by pivoting it about its central axis. A moveable trestle is provided to support the transtainer while its trunnions are attached to the foundation by means of hydraulic jacks.

(d) Cleveland Pneumatic Tool Company. (Figure 5-22B,page 5-56)

1. Description:

This concept considers erection of a 2 million lb. booster. The equipment consists of erector assembly, transporter, harness assembly and diesel-electric mover. The erector is a multi-truck railway vehicle equipped with fail safe brakes and is designed for handling the booster at the casting and firing

site. It is U-shaped to receive the motor on its transporter through the open end and to facilitate transfer of the booster to the erector.

Hydraulic support jacks, integral with the erector frame, are located at strategic points to stabilize the erector during handling and transfer of the load. Additional stabilization and support are provided by stabilizer frames which are attached to the lift cylinders.

Double stage, hydraulic lift cylinders, in conjunction with two multi-stage telescoping tilt cylinders, provide the means of lifting and rotating the motor case. The cylinders are designed for use with a 5000 psi hydraulic system.

The harness yoke is of the "clam-shell" type, opening and closing are accomplished by hydraulic actuation. The inner surface of the harness is designed to provide a uniform load distribution throughout the supported areas by means of an impregnated nylon sling.

2. Budgetary Cost Estimate:

Erector, transporter and diesel prime mover - $4,000,000.

(e) Cleveland Pneumatic Tool Company. (Figure 5-23, page 5-57)

1. Description:

This concept is similar to the one projected previously, except that erection of an 8 million lb. booster is contemplated. No external framing or support jacks are used. Lift and rotation about the C. G. of the motor is provided by two four-stage telescoping hydraulic tilt cylinders and six hydraulic lift actuators. These actuators are housed in the erector frame.

2. Budgetary Cost Estimate:

Transporter, erector and diesel prime mover - $6,000,000.

(f) U. S. Navy, Bureau of Yards and Docks. (Figure 5-24, page 5-58)

This figure shows a sequence of operations for placing the motor in a pit-type manufacturing/static test facility. The motor case on its transporter is tilted to vertical position by means of a tilting fixture and a crane. The crane will also place and remove the mandrel and casting fixtures. Following tilting, the motor case will be lowered into the pit by a platform which is actuated by hydraulic pin jacks or a LeTourneau unit.

(g) New York Shipbuilding Corporation. (Figure 5-25A,page 5-59)

This scheme raises the empty motor case by means of a tower and winches. Hydraulic jacks are provided in the base of the tower to lower the motor to its final position. When laying down the fueled motor, auxiliary winches pull the suitcase until gravity begins to act.

(h) New York Shipbuilding Corporation. (Figure 5-25B,page 5-59)

This system raises the empty motor case by lifting jacks. These may be screw jacks or similar. Hydraulic jacks are provided in the base of the erection tower to lower the motor to its final position. When laying down the fueled motor, auxiliary winches pull the suitcase until gravity begins to act.

(i) New York Shipbuilding Corporation. (Figure 5-26, page 5-60)

In this case, an inclined track is used to lift the motor from horizontal to vertical position. The upper end of the suitcase is pulled up this inclined track by a winch and pulley system, while the lower end rides on its own track. Hydraulic jacks are provided in the base of the erection structure to lower the motor to its final position. When laying down the fueled motor, auxiliary winches pull the suitcase until gravity begins to act.

(j) Morgan Engineering Company. (Figure 5-27, page 5-61)

In this scheme, two 800-ton gantries are used to remove the motor from the barge and place it onto a tilting bed. The tilting bed erects the motor and the gantries carry it to the casting pit. Following loading, the gantries move the motor back to the tilting bed and the procedure is reversed.

(k) Kaiser Industries Corporation. (Figure 5-28A, page 5-62)

This scheme utilizes a flat deck, steel, sea-going barge of conventional design. The barge is brought to the casting pit and sunk onto a prepared foundation. The case in the structural cradle is brought from the barge and erected with a winching system, as shown.

(l) Kaiser Industries Corporation. (Figure 5-28B, page 5-62)

This scheme is similar to the one presented above (Figure 5-28A,) except that, in this case, the barge is of special deep well construction. This permits tilting operations to proceed on the barge and eliminates horizontal transfer of the motor case and loaded motor.

(m) Kaiser Industries Corporation. (Figure 5-29A, page 5-63)

This scheme is also similar to Figure 5-28A but in this case the Structural Cradle is pulled up an incline towards the pouring position.

(n) Kaiser Industries Corporation. (Figure f-29B, page 5-63)

This scheme is similar to Figure 5-28A. Horizontal motion of the case is minimized since pivoting occurs about a point in the forward section of the case. The smaller horizontal motion must be traded off with the requirements of heavier hoisting provisions.

(2) Wet Schemes.

(a) AMF. (Figure 5-30, page 5-64).

1. Description and Operation:

The motor case, in its caisson, is transported to this facility via barge (Figure 5-30A, page 5-64). The barge is ballasted and the motor case caisson floats free, controlled by two winches. These winches guide the caisson into a set of curved guide rails. The rails guide the motor into vertical position as the water is pumped out. It takes approximately 24 hours to empty the submerged facility using a 3000 gpm pump (see Figure 5-30B, page 5-64). The container is specially designed to permit free circulation of heated air during the curing operation. If the motor is destined for use at the launch facility, the caisson is never removed during the manufacturing operation. Figure 5-30C, page 5-64 shows the propellant bin support structure. This structure contains partitions for six propellant bins. The propellant bins are loaded into this structure by the portable crane. The crane will also be used for removal of the mandrel and emplacement of the nozzle. For static test, the caisson is removed after the curing operation. Removal is facilitated by removable work platforms at appropriate levels and by the crane. Figure 5-30D, page 5-64 shows the motor with the caisson removed ready for static testing. Upon completion of static test the caisson is reassembled and the empty case floated out of the facility.

2. Budgetary Costs:

Construction Cost	11.4 million
Mechanical Equipment Cost Winches 50 Ton Crane	1.6 million

Propellant Curing System
Work Platform and Personnel Elevating System
Pumping Equipment
Caisson Shipping Container
Power System

Total Approximate Cost 13.0 million

(b) Frederick R. Harris (Figure 5-31A, page 5-65)

1. Description of Construction Technique:

Due to the problems of tremendous hydrostatic pressures and uplift, the Harris concern proposes to construct the entire fueling and test pit as a large caisson built on its side at ground level. The caisson would be constructed with hollow walls which would eventually be filled with sand or dredged material as it were found suitable. Dredging for the approach lock would proceed simultaneously with construction of the caisson.

When the caisson is completed, dredging would continue around and under the caisson, eventually floating it while still on its side; dredging would then continue to the required depth. The caisson would then be careened and set on the bottom by flooding the hollow walls filled, and backfilling completed. The lock could be constructed by conventional use of well points, entrance cofferdam, etc. The transporter would be essentially a conventional type of small steel floating drydock.

2. Budgetary Cost Estimate:

Dredging, Backfilling and Disposal of Excess	$ 5,450,000
Fueling and Testing Pit	3,070,000
Lock and Gates	2,760,000
Transporter, Complete	1,000,000
Mechanical & Electrical Services, Steam Generating Plant, Pumping Plant, Standby Power, etc.	500,000
Miscellaneous Fittings (Lock & Pit)	150,000
100 Ton Overhead Travelling Crane and 500 ft. Craneway	500,000
	$13,430,000
Contingency 25%	3,370,000
	$16,800,000

(c) New York Shipbuilding Corp. (Figure 5-32B, Page 5-65)

1. Operational Procedure.

1) The empty motor case is placed in the suitcase at the manufacturing facility and loaded onto the deck of the transporting barge for transfer to the fueling site. Proper supports for the suitcase and motor case are provided.

2) At the fueling site, the floating platform is ballasted with water on one side so that it floats on edge at the correct draft.

3) The transporting barge is brought to the floating platform, and the two are connected, with the nose of the empty motor casing toward the floating platform.

4) The floating platform is ballasted with water to rotate the transporting barge and empty motor case into a vertical, tail-up position for fueling. (The motor case can also be moved ashore for fueling as indicated in steps 9 and 10). This procedure will leave the floating platform available for handling another motor case and transporting barge.

5) After the motor case is fueled, the floating platform is de-ballasted to rotate the transporting barge and motor case back down into transfer position.

6) At the launch site, the floating platform is again ballasted with water on one side so that it floats on edge at the correct draft.

7) The transporting barge is brought to the floating platform, and the two are connected, with the tail of the fueled motor casing toward the floating platform.

8) The floating platform is ballasted with water to rotate the transporting barge and fueled motor case into a vertical, nose-up position.

9) The floating platform, carrying the transportation barge and fueled motor case in a vertical nose-up position, is connected to a dock through toggles which prevent the

barge from moving when the fueled motor is case is transferred ashore. Railroad tracks installed on the barge are automatically lined up with shore-side tracks when the toggles are connected.

10) A railroad car is run onto the barge under the tail of the fueled motor case. The weight of the motor case is taken onto the car through hydraulic jacks. The motor case is disconnected from the transporting barge and taken ashore.

(d) New York Shipbuilding Corp. (Figure 5-32, page 5-66)

1. Description:

The basic equipment associated with this concept consists of a small barge about 120 x 40 feet and a small floating drydock-type structure. The barge will contain one motor case and serve as a transporting container from the case manufacturer to the fueling site. It will also serve as the enclosure for the fueling environment. The barge will be provided with trunnions at its sides, located at the center of gravity of the motor case. The trunnions will be used to properly position the barge and motor case. The barge will remain with the motor case until it arrives at the launch site.

The floating drydock structure will be about 130 feet long, 102 feet wide and 65 feet high. It is open at one end to allow the barge to be floated in position and to permit removal of the motor case at the launch site.

2. Operation:

NOTE: The barge is complete with saddles for supporting the fuel motor case horizontally and with a support structure to match the casing skirts at either end when the fueled motor is vertical. A major portion of the deck is removed to install the motor case.

1) The rocket motor case is placed in the barge at the case manufacturing facility. The motor is firmly strapped and restrained from motion inside the barge in all directions. The motor case contains temporary internal bracing.

2) The top deck is bolted in place. (The draft of the barge is about 3 feet).

3) In this condition, the barge is transported through inland waterways to the fueling site.

4) At some location near the fueling site, where the depth of water is a minimum of 60 feet, natural or dredged, the barge and the floating drydock structure are assembled. The drydock is lowered until the barge can be floated into it, and the trunnions on the barge are engaged in the journals on the deck of the drydock.

5) The barge is fixed in place in the drydock and the drydock is raised. The fully pumped out, the drydock will have a draft of about 6 feet.

6) The drydock and attached barge are towed to the fueling site.

7) At the fueling site, the barge is rotated to vertical position with the motor case nose downward. This is accomplished by rotating the barge in the trunnion pedestals using cables and winches.

8) The aft end of the barge is removed for access and arrangements are made for temperature and humidity control of the interior of the barge.

9) The fuel is loaded in the casing in this position. As the fuel is loaded, the draft of the drydock increases to about 12 feet.

10) When fueling is complete, the exit cone section is bolted to the aft closure ring.

11) The launching pad supports are installed.

12) The aft end of the barge is closed in for protection of the motor during transit to the launch site.

13) The drydock and the barge are towed to the launch site.

Figure 5-32B, page 5-66 presents the next step in the sequence of handling operations projected. Upon arrival of the drydock and barge at the launch site, the following sequence of operations occurs:

1) The barge is rotated to vertical position in the trunnions with the nose end up.

2) The deck and aft end of the barge are dismantled.

3) The drydock positions the motor over the car of the Marine railway. (Permanently installed at the site).

4) The fueled motor and barge are lowered into place on the car by flooding the drydock. (The drydock shall be ballasted by pumping as the load is transferred to the railway car).

5) The motor is disconnected from the barge.

6) The drydock and barge are towed away from the Marine railway pier.

7) The motor is transferred to the launch platform on the Marine railway.

c. Loading, Transportation and Unloading of the Fueled Motor Case.

In all the schemes presented, the loading or unloading of the fueled motor case from the barge or transport vessel is similar to that of the empty motor case (as discussed previously in this section) Figure 5-33A, page 5-67 supplied by the DeLong Corporation could also be considered as a means of loading and unloading the fueled motor case from its transport vessel.

This method uses a DeLong elevating mobile transfer platform to take the motor from the dock to a transport ship. In this concept the motor case is rolled both on and off the mobile transfer platform. Another method suggested by the DeLong Corporation is shown in Figure 5-33B, page 5-67 In this method the motor is rolled onto a transport barge which is aboard the DeLong mobile platform. The mobile floating platform is towed to a waiting LSD (Landing Ship Dock) stationed off-shore. The platform is then partially submerged and the barge with the motor on board is floated into the semi-submerged LSD. In both schemes, stability of the mobile transfer

platform during unloading is provided by the hydraulically actuated legs. Additional details on the lifting capabilities of the DeLong jacks are given in Section 8.

d. Vertical Erection at the Launch Site.

The next operation associated with handling of the monolithic motor is vertical erection of the motor at the launch site. One possible method of motor erection and transfer is by a conventional mobile service tower structure equipped with an overhead crane. (See Figure 5-34A, page 5-68). This method requires that the aft end of the motor case be equipped with a trunnion mount for initial vertical rotation. The gantry will be capable of supporting the entire weight of the motor. With the motor in vertical position, the gantry will transfer it directly to the launch pad for clustering or to an intermediate booster assembly station.

It is also possible to use the AMF transporter projected in Figure 5-20, page 5-54 to aid in erection of the motor. This transporter will remove the motor from the barge and bring it to an erection pit as shown in Figure 5-34B, page 5-68. This pit will be equipped with a set of DeLong hydraulic jacks and a moveable platform. Prior to arrival of the motor, a vertical transporter will be placed on this platform and lowered into the pit, using a winch and a C. G. pivot. With the motor in vertical position, the hydraulic jacks will raise the platform thus mating the motor to the vertical transporter. The platform will then be raised to ground level and the motor transported to the booster assembly area.

e. Booster Assembly.

As was the case of the assembly of boosters from segmented motors, the unitized booster can also be assembled by the conventional on-pad method or off the pad as in the Integrated Transfer Launch system.

(1) Conventional On-Pad Assembly.

Figure 5-35, page 5-69 shows two schemes projected by AMF for fixed launch complex concepts.

Figure 5-35A, page 5-69 projects a fixed service tower for on-pad assembly of the entire vehicle. The individual motors are transported to the pad in the vertical position. A sheer-leg derrick is employed to lift each motor onto its support structure. Sliding door and "clam-shell" enclosures are provided for environmental control of the booster and upper stages. It is the

assumption in this case that the vehicle will fire out of the fixed structure. With a slight modification in structure, the fixed tower could accommodate bridge cranes rather than the sheer-leg derrick.

Figure 5-35B, page 5-69 projects the use of two different cranes for erecting the vehicle. The overhead bridge crane is used only to assemble the booster stage. Its capacity is based on the weight of the individual motors. For this scheme it is assumed that the motor arrives at the pad in a vertical attitude. The remainder of the vehicle is assembled using the hammerhead crane at the top of the mobile tower. Environmental protection is provided by the clam-shells and sliding doors. The mobile tower with the clam-shells retracts prior to vehicle launch. Since the first stage assembly bridge crane is a fixed structure, it remains at the pad during launch.

It should be noted that the above concepts apply equally well to segmented booster vehicles. The segments can either be erected into boosters on the launch pad or individual motors can be assembled elsewhere and transferred to the pad for booster assembly. The methods of booster assembly shown are not affected by either motor size or the number of motors in the cluster.

Another point to be noted is that vehicles with larger payloads (on the order of 500 tons) will require that the high capacity crane be located at the top of the service tower rather than at booster height, thus serving not only the booster but the payload as well.

Figure 5-36, page 5-70 shows a scheme supplied by the Todd Shipyard Corporation for assembling a cluster of four motors at the launch pad. A peninsula-type pad is provided with access to all four sides by barge and causeway. The removable hoist structure at the center of the pad is used to raise two loaded motors from the barge simultaneously. This balances the bending moments, making the hoist essentially a compression loaded structure. The tower is guyed, however, as a precaution against accidental moment unbalance. When the motors are in vertical position, fixed support pad structures must be emplaced beneath them to support the load. Stability of the first pair can be temporarily maintained by securing them to each other through the hoist tower.

After the second pair of motors is erected and all four are permanently strapped together, the hoist column, which is greater in height than the booster stage, can be disassembled and removed using a standard crawler crane with a long boom. After both motors are clear of the barge, the latter can be returned to the processing plant for the remaining pair.

Figure 5-37 and 5-38, pages 5-71 and 5-72 were supplied by the Morgan Engineering Company. Both illustrations portray on-pad assembly methods. The operational sequence is as follows:

1) The motor is lifted from the barge by a 1600 ton gantry.

2) The motor is transported to the 90 degree tilting bed and emplaced.

3) The motor is tilted to the vertical and listed from the tilting bed with the 1600 ton gantry.

4) The motor is transported to the launch pad.

5) The procedures are repeated for the other solid motors in the booster cluster.

The only difference in the two concepts lies in the fact that the deep pit concept requires that the vehicle be assembled on an elevating platform. At the completion of vehicle assembly, the platform will be raised with the aid of jacks to a sufficient height to allow for emplacement of a flame deflector.

Another method of on-pad assembly is depicted in Figure 5-39A, page 5-73. In this concept the solid motor is shown being transported to the pad in the horizontal attitude. The aft end of the motor is equipped with a support ring containing pins which engage the trunnion mount. These trunnion mounts have integral hydraulic jacks to aid in pin emplacement on the launch stand. The upper stages are assembled with the aid of an auxiliary crane. Clam-shells and sliding doors are again required for environmental protection. With the completion of vehicle assembly, the environmental clam-shells are retracted as shown in Figure 5-39B, page 5-73 and the vehicle is launched through the tower.

(2) Integrated Transfer Launch System.

Figure 5-40, page 5-73 shows the booster being assembled on an ITL transporter with the aid of fixed overhead cranes at the docking facility. The transporter shown could be either a crawler, a pneumatic-tired vehicle or a rail-mounted device. Upon completion of booster assembly, the booster is taken to the pad or to an intermediate facility for mating with the rest of the vehicle.

Figures 5-41 and 5-42, pages 5-74 and 5-75 project methods of booster assembly for an ITL system.

Figure 5-41, page 5-74 is an AMF scheme for booster assembly at the pad. This scheme is predicated on a four-motor booster. The motors are transferred to the pad in vertical position on individual motor transporters.

Assembly of the booster is performed on a DeLong-type hydraulically jacked platform. This platform will, during assembly of the booster, occupy the space normally reserved for the flame deflector which, in this case, is a portable rail-type unit. For assembly of the booster the platform will be flush with ground level. This platform will have an insert where the exhaust flame opening is normally located. This insert remains at ground level when the platform is raised to launch position. The booster assembly operation is as follows:

1) The motor arrives at the pad in the vertical attitude on its transporter.

2) The transporter is positioned on the moveable platform. It should be noted that the size of the individual motor transporters is a function of the number of motors in the booster and their size and location.

3) Temporary supports are attached to the motor support points. The lower end of the temporary supporting structure is equipped with hydraulic jacks for raising the motor off the individual transporter.

4) The individual motor transporter is removed.

5) Two of the three final launch support release mechanisms are installed. (The portion of the motor facing the center of the booster is still supported by the temporary support structure).

6) The remaining three motors are positioned as in steps 1) through 5) above.

7) The four motors are then tied together with their clustering structure.

8) The upper stages are brought to the pad on a U-shaped (ITL) transporter which spans the launch deck opening and are mated to the booster stage. Other methods of emplacing the upper stages can be found in Figure 5-43, page 5-76 which will be discussed at the end of this section.

9) The temporary center support structure is detached at its upper end. (It should be noted that at this time the booster assembly is supported at eight places about its periphery).

10) The platform is raised to launch position with the DeLong jacks. The elevated height of the platform is based on the size of the flame deflector.

11) Upon reaching launch position, the platform is locked into place with hydraulic rams.

12) The temporary center support structure is removed and the flame deflector rolled into position.

13) The center vehicle support structure (which is part of the flame deflector assembly) is attached.

The vehicle is now ready for launch.

Figure 5-42, page 5-75 is an AMF scheme projected from the Todd concept presented in Figure 5-36, page 5-70. In this concept the motors are assembled on a transporter rather than on a fixed shore-based pad. The actual erection operation is the same as projected by Todd Shipyard Corporation. The only difference occurs in the positioning of the booster transporter.

1) A transporter with removable hoist structure is emplaced on a hydraulically-operated platform.

2) The platform lowers until its base is flush with ground level.

3) Two motors are brought to the erection site.

4) Two motors are positioned on opposite sides of the removable hoist structure.

5) The hoist structure raises two motors simultaneously. This balances the load making the column essentially a compression member. The tower is guyed during this operation against possible unbalance.

6) Temporary motor supports are emplaced.

7) Items 3-6 are repeated for the other two motors.

8) All four motors are permanently strapped together and the central hoist column is removed in sections with the aid of a long boom on either a crawler or truck crane.

9) Upon completion of booster erection, the platform is raised to ground level and the transporter and booster are transferred to the final vehicle assembly station.

With the booster on a transporter, two possible ways for emplacing the upper stages have been projected by AMF. These can be found in Figure 5-43, page 5-76. Scheme A shows the booster being transported to the pad and its final position on the pad. An environmental closure for the booster has been provided. The upper stages are brought to the pad on a U-shaped ITL transporter which straddles the booster by use of the transfer bridge. Actual mating can be accomplished with the aid of jacks located on either the booster transporter or the upper stage transporter.

Scheme B also shows the booster arriving at the pad and in its final position on the pad. Additional details on crawler-type transporters are presented in Section 8. The upper stages arrive on a separate transporter and are mated to the booster by using an enclosed structure containing DeLong jacks. This enclosed structure could, in the event of a hurricane, remove the upper stages and provide protection at the pad area. An environmental enclosure is also provided for the booster stage to be used during vehicle assembly.

f. Evaluation of Launch Site Concepts.

Section 11 presents a discussion of the various possible operational systems capable of handling the 260-inch monolithic motor at the launch site.

It must be pointed out that a conclusive evaluation of these systems is not feasible at this time since a number of ground rules must be firmed up before a detailed evaluation effort can be undertaken. Section 11 discusses the various systems and points out the important ground rules and trade off parameters.

The only method of transportation which has not been evaluated as part of this study program is water transportation of large solid motors in the vertical attitude. This method of transportation is limited to open waters because of the fixed bridges (55 feet high) located along the inland water. In order to determine the feasibility of ocean going transport of solid motors in a vertical attitude, a study of special vessels specifically designed for this operation,is required. This special vessel will then have to be traded-off against the cost of erection facilities which are required for the horizontal transportation mode.

A significant disadvantage of the vertical transportation mode is the fact that the finished motor must be turned 180° at the Manufacturing/Static Test site to accomplish the required change from a nozzle-up position during pouring to a nozzle down position for eventual clustering at the pad.

FOR DISCUSSION REFER TO PAGE 5-29

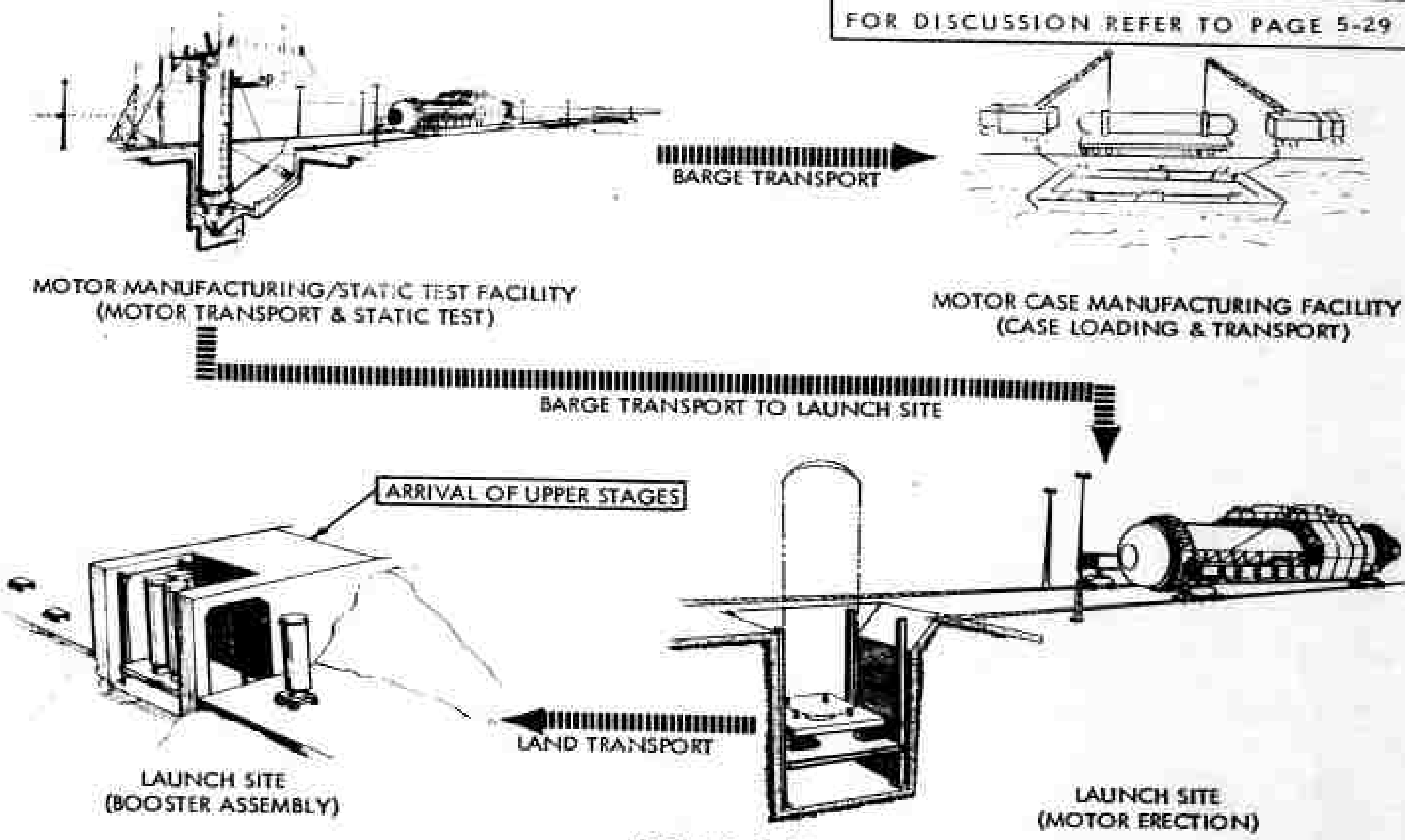


FIGURE 5-16
OVERALL FLOW CHART - MONOLITHIC MOTORS

FOR DISCUSSION REFER TO PAGE 5-30

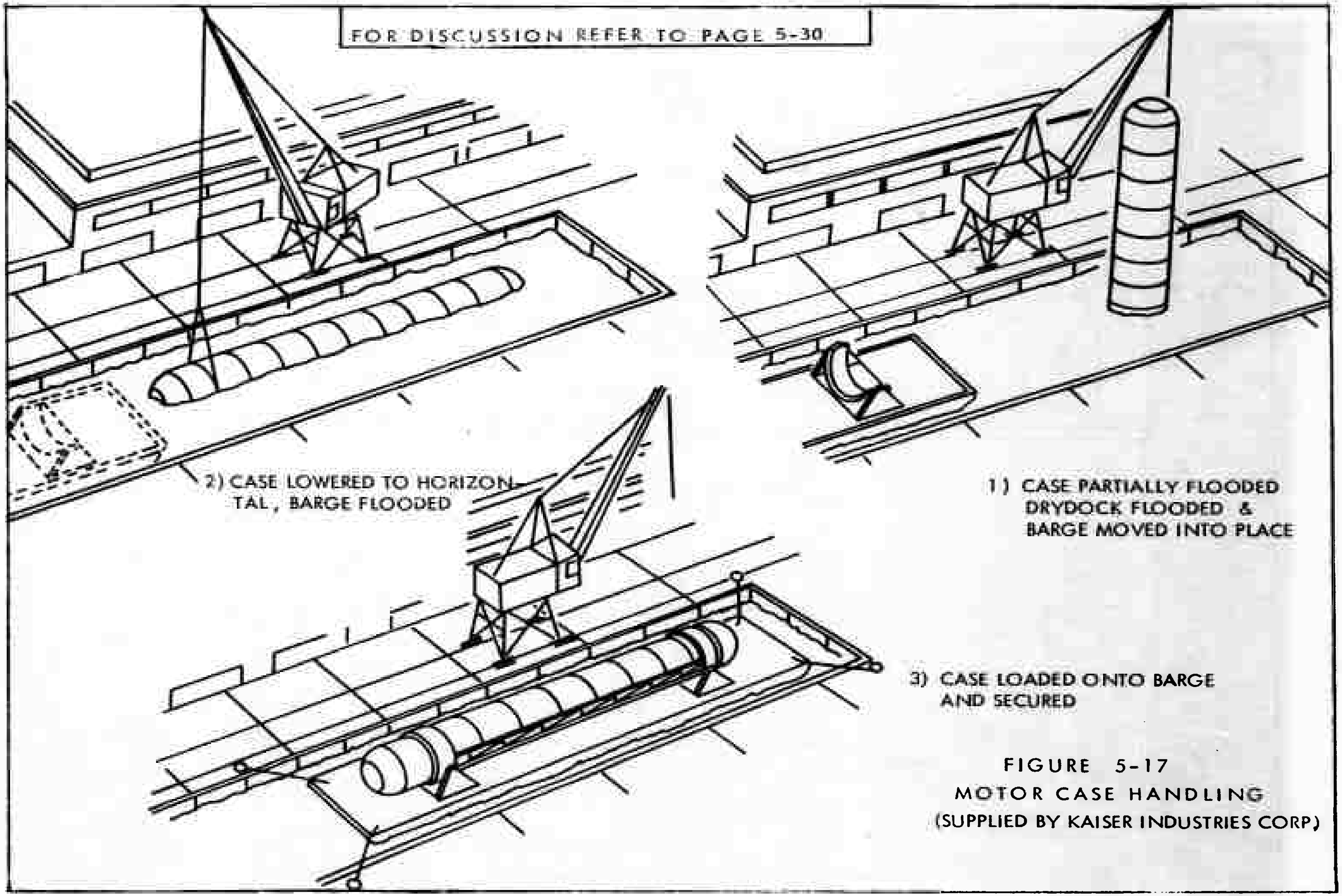
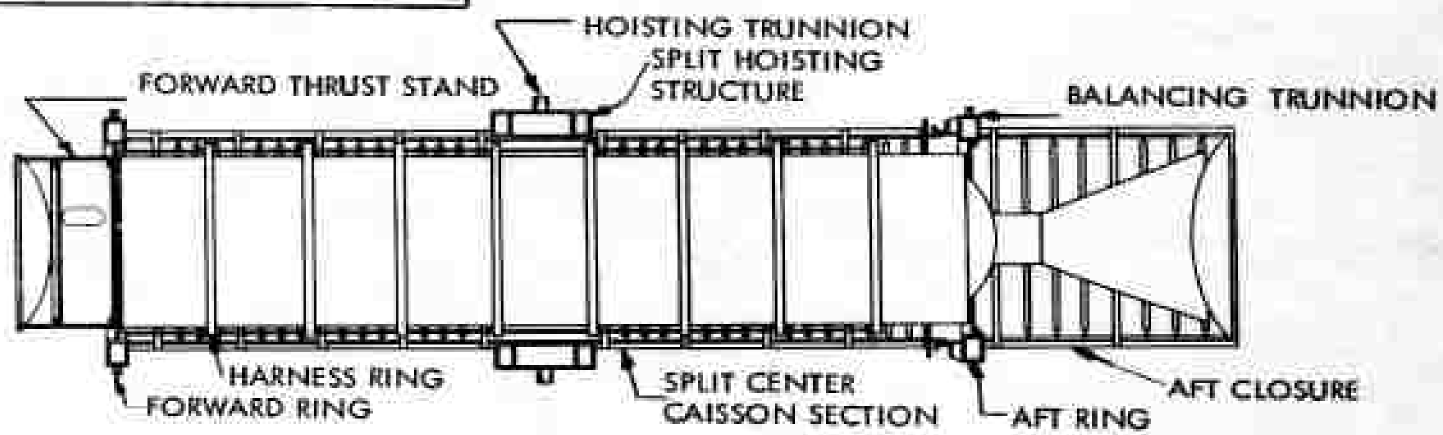
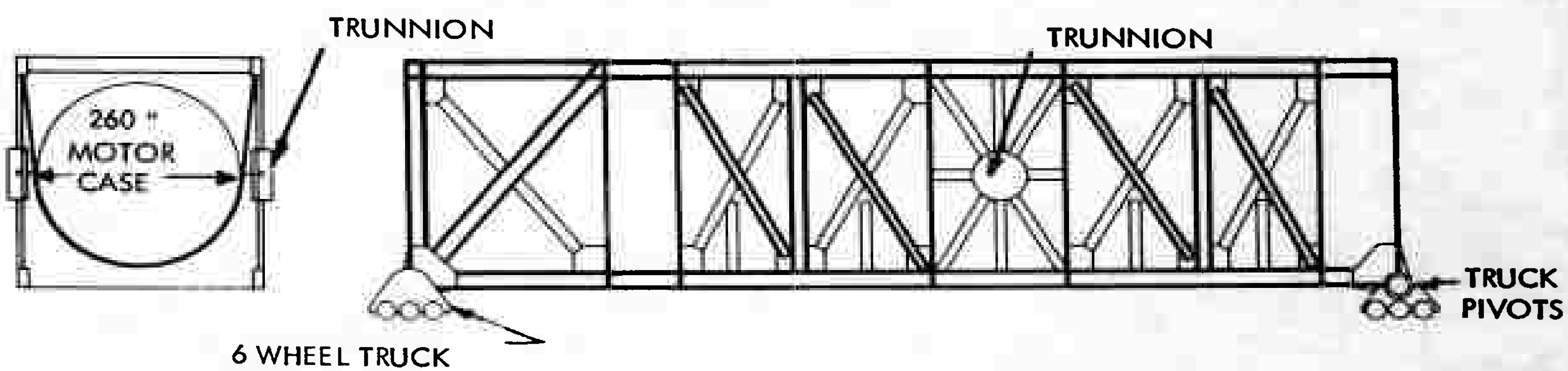


FIGURE 5-17
MOTOR CASE HANDLING
(SUPPLIED BY KAISER INDUSTRIES CORP)

FOR DISCUSSION REFER TO PAGE 5-30



A. AMF CAISSON ASSEMBLY



B. STRUCTURAL SUITCASE FOR HANDLING MONOLITHIC MOTORS (SUPPLIED BY NEW YORK SHIPBUILDING CORP)

FIGURE 5-18
MONOLITHIC MOTOR SHIPPING CONTAINERS

FOR DISCUSSION REFER TO PAGE 5-31

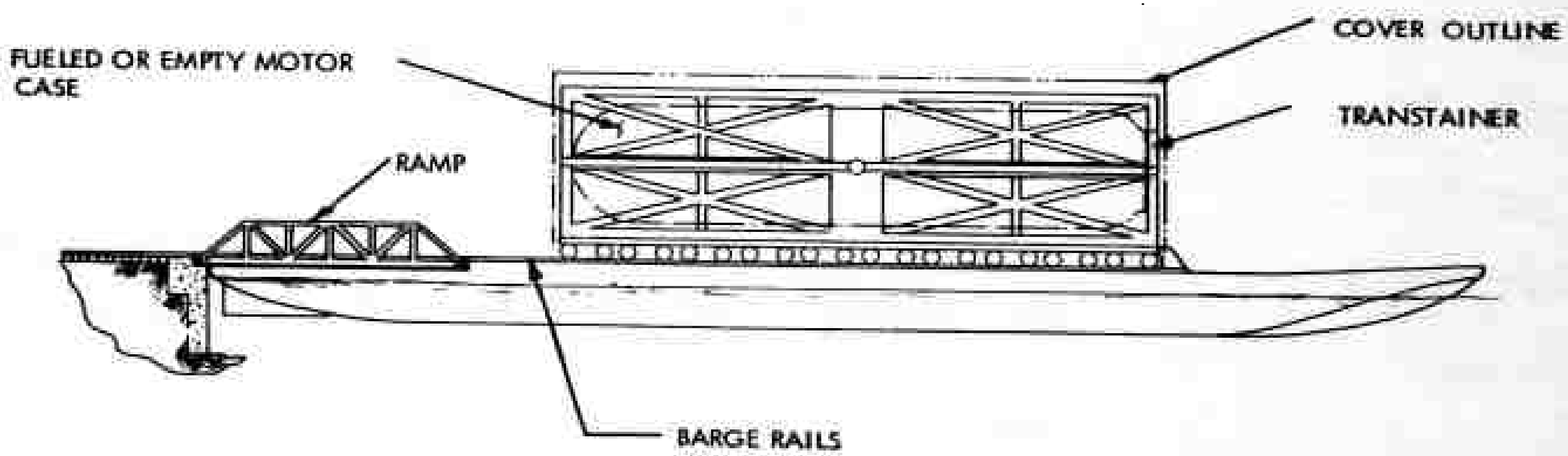


FIGURE 5-19

UNITIZED MOTOR TRANSPORT
(SUPPLIED BY TODD SHIPYARDS CORP.)

FOR DISCUSSION REFER TO PAGE 5-33

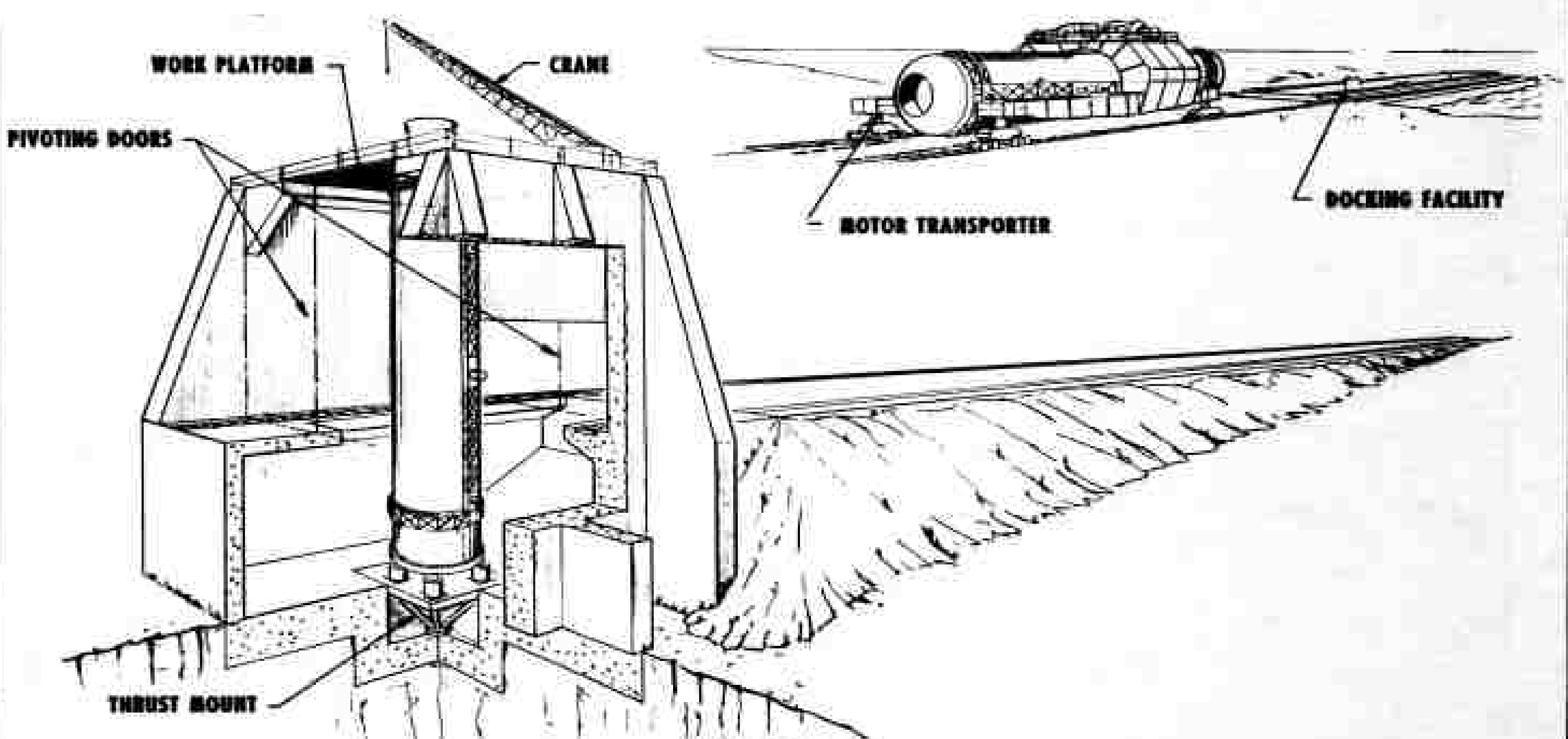


FIGURE 5-20
ABOVE GROUND MANUFACTURING/STATIC TEST FACILITY

FOR DISCUSSION REFER TO PAGE 5-55

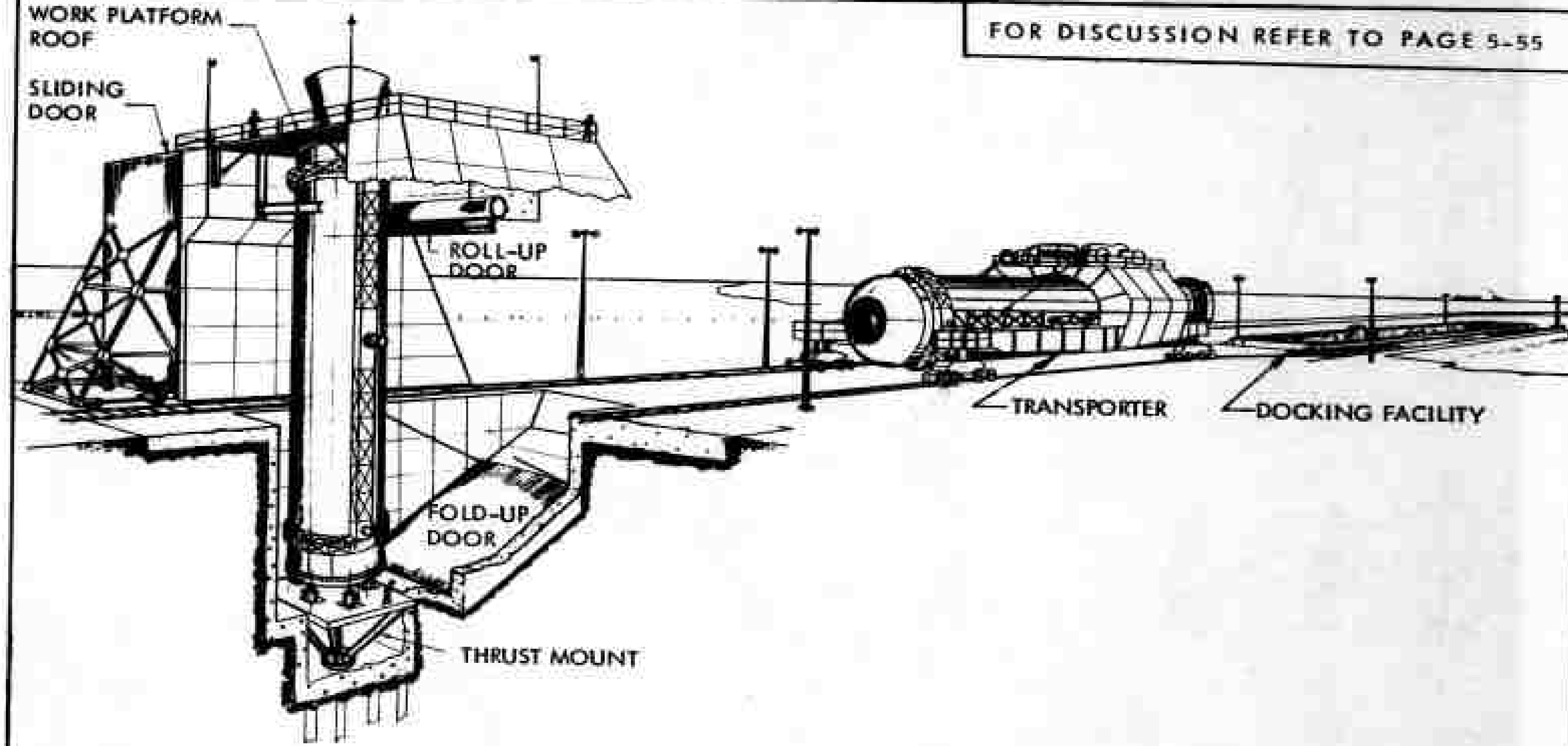
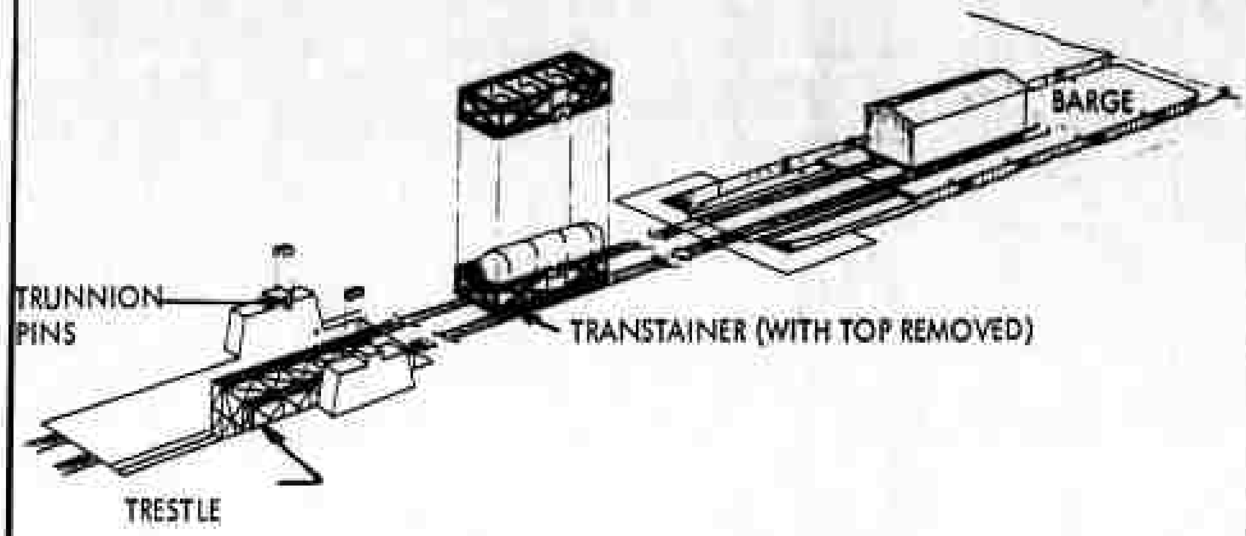


FIGURE 5-21
260-INCH MOTOR LAND BASED MANUFACTURING AND STATIC TEST FACILITY

FOR DISCUSSION REFER TO PAGE 5-34



A. TODD SHIPYARDS CORP. CONCEPT

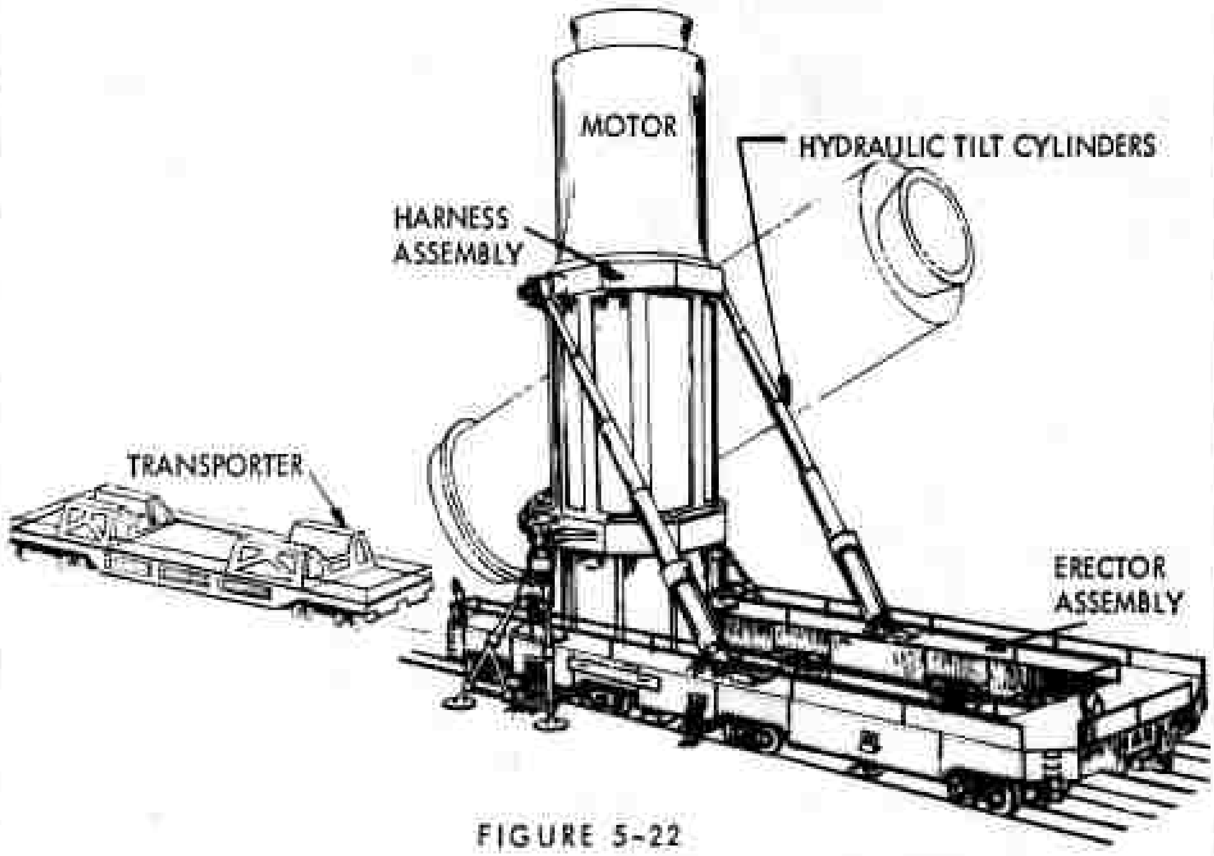
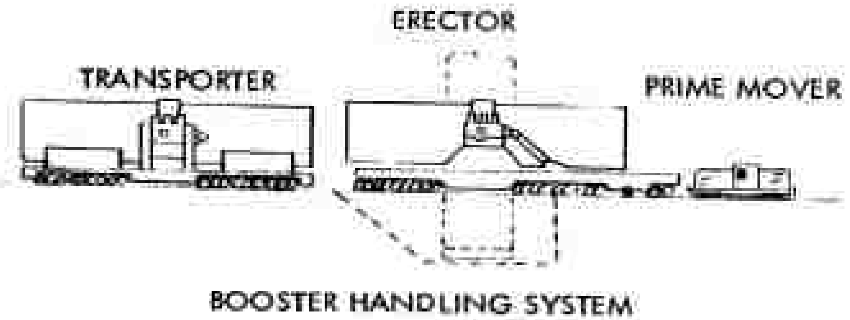


FIGURE 5-22

B. CLEVELAND PNEUMATIC TOOL CO. CONCEPT

DRY CONCEPTS - MANUFACTURING/STATIC TEST FACILITY

FOR DISCUSSION REFER TO PAGE 5-35



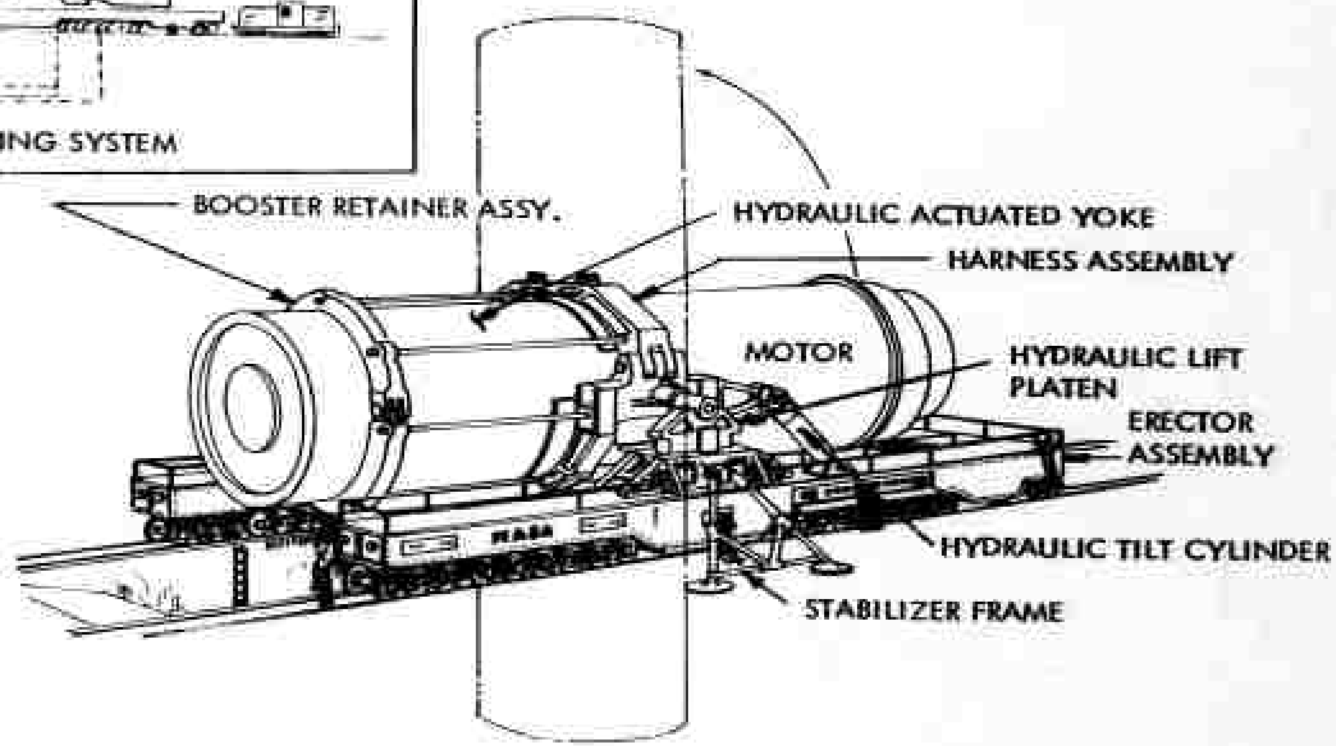
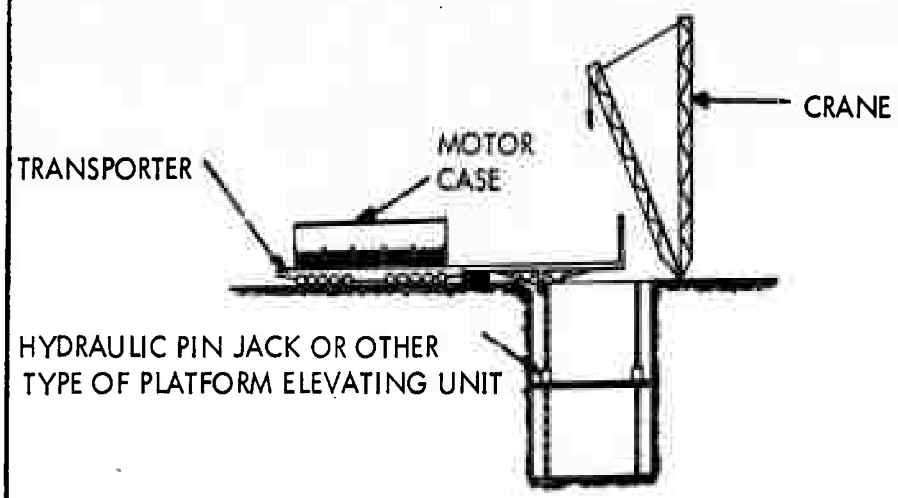


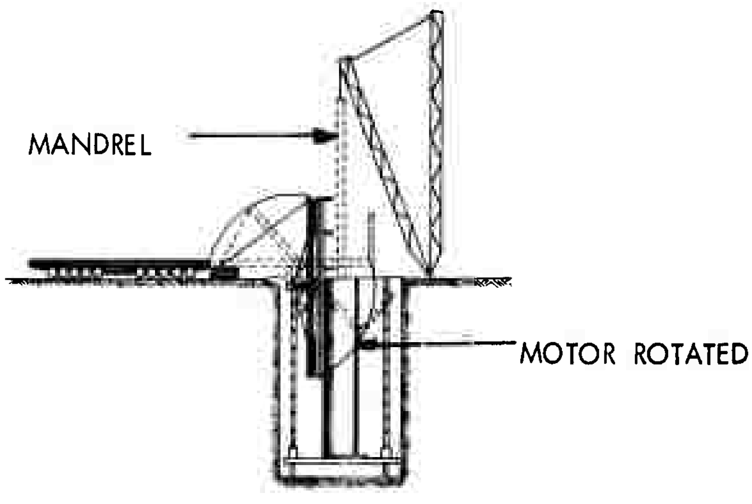
FIGURE 5-23

MOTOR ERECTION AT MANUFACTURING/STATIC TEST FACILITY
(SUPPLIED BY CLEVELAND PNEUMATIC TOOL CO. INC.)

FOR DISCUSSION REFER TO PAGE 5-35



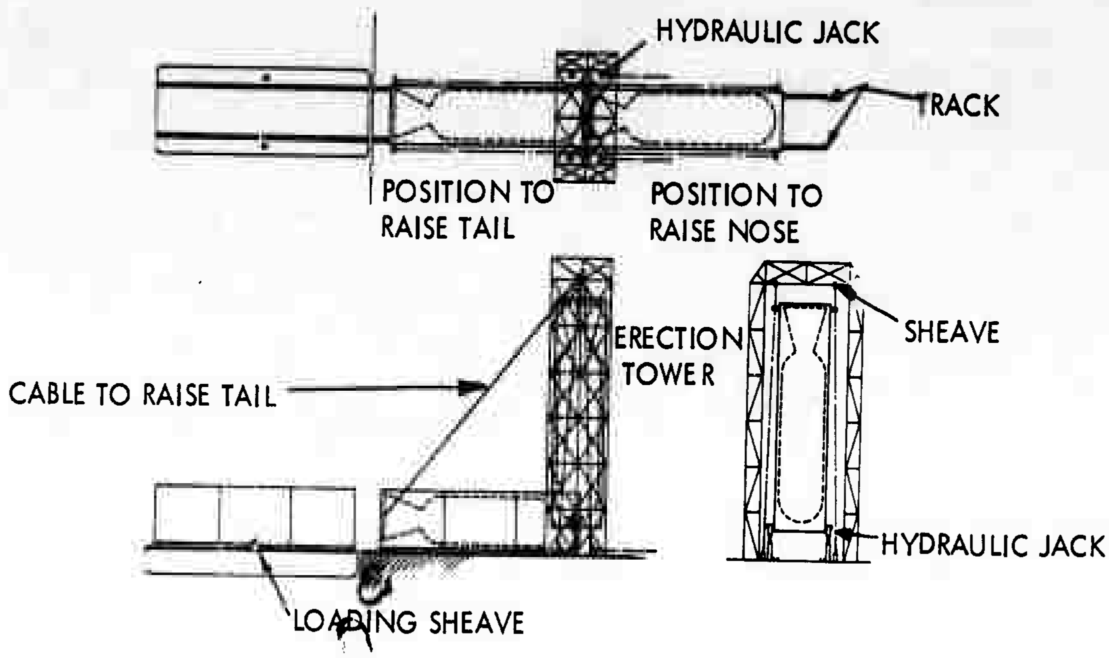
1) MOTOR ARRIVAL



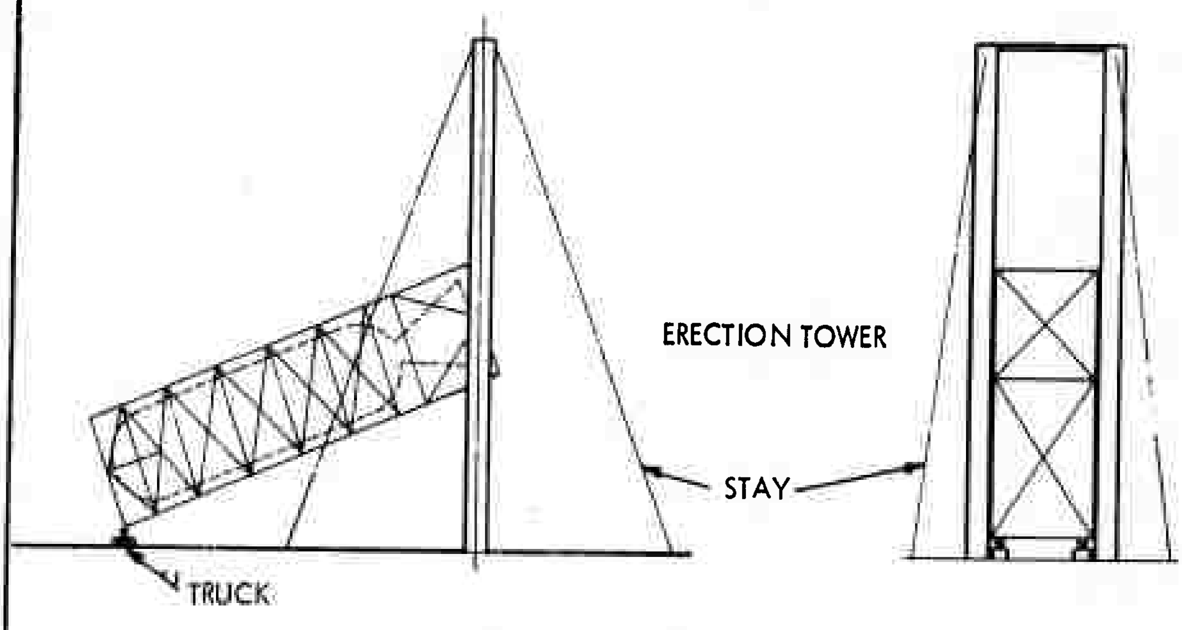
2) MOTOR INSERTION

FIGURE 5-24
MOTOR CASTING STATION
(SUPPLIED BY BUREAU OF YARDS AND DOCKS, USN)

FOR DISCUSSION REFER TO PAGE 5-36



A. TOWER, CABLE AND SHEAVE METHOD



B. SHORT JACK METHOD

FIGURE 5-25

MOTOR MANUFACTURING/ STATIC TEST (DRY CONCEPT)
(SUPPLIED BY NEW YORK SHIP BUILDING CORPORATION)

FOR DISCUSSION REFER TO PAGE 5-36

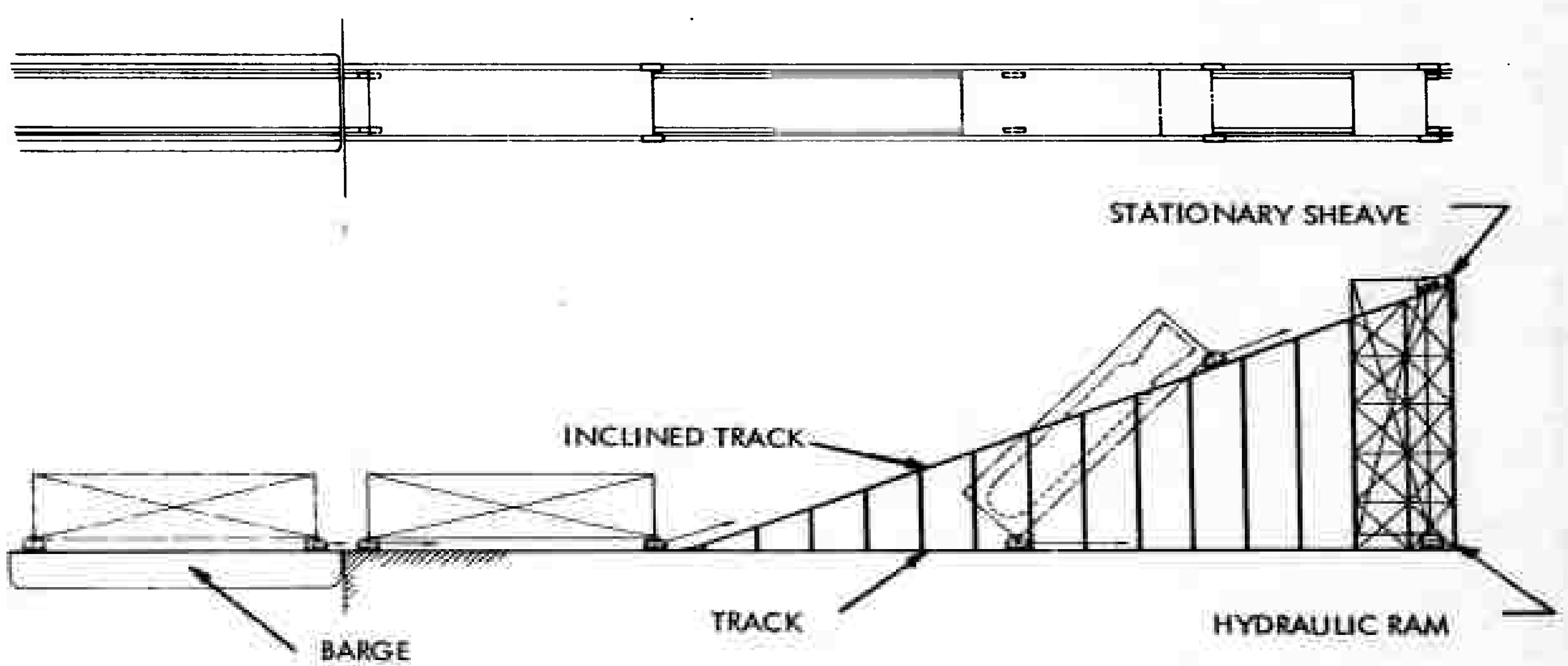


FIGURE 5-26

INCLINED TRACK CONCEPT FOR MOTOR MANUFACTURING/STATIC TEST
(SUPPLIED BY NEW YORK SHIPBUILDING CORP.)

FOR DISCUSSION REFER TO PAGE 5-36

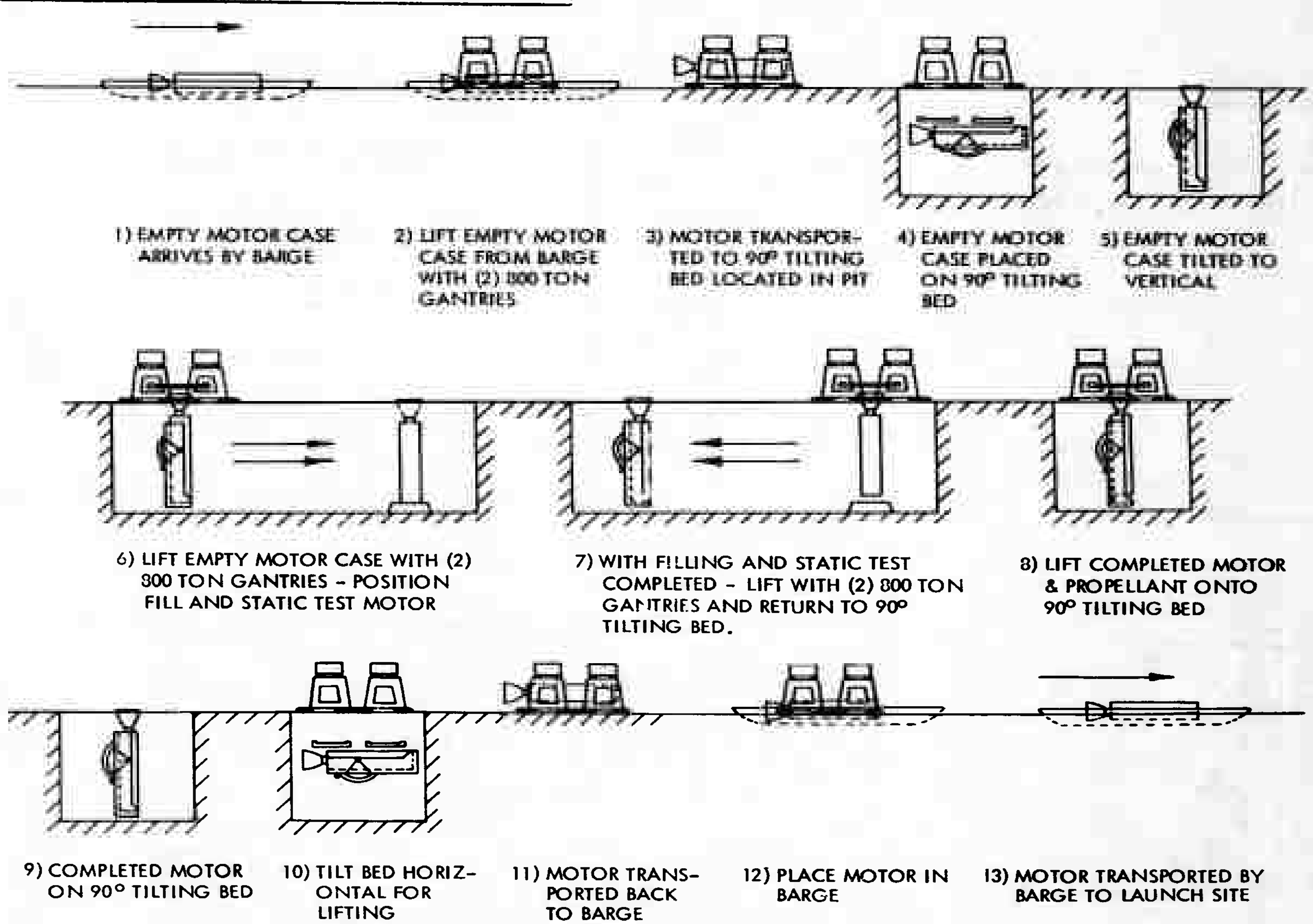
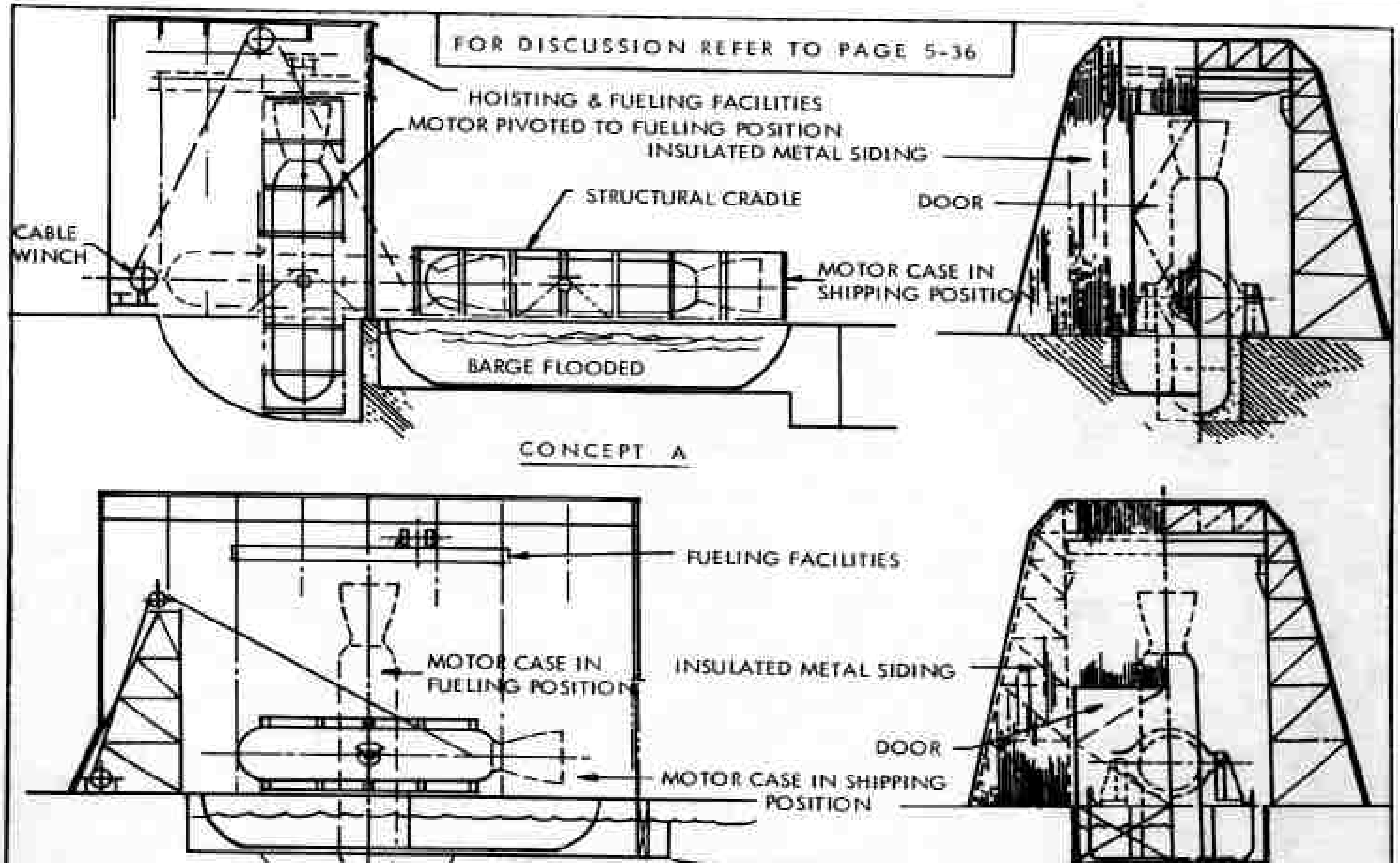


FIGURE 5-27
MANUFACTURING/STATIC TEST FACILITY
(SUPPLIED BY MORGAN ENGINEERING CO.)



CONCEPT B

FIGURE 5-28
MOTOR MANUFACTURING FACILITY
(SUPPLIED BY KAISER INDUSTRIES CORP.)

FOR DISCUSSION REFER TO PAGE 5-37

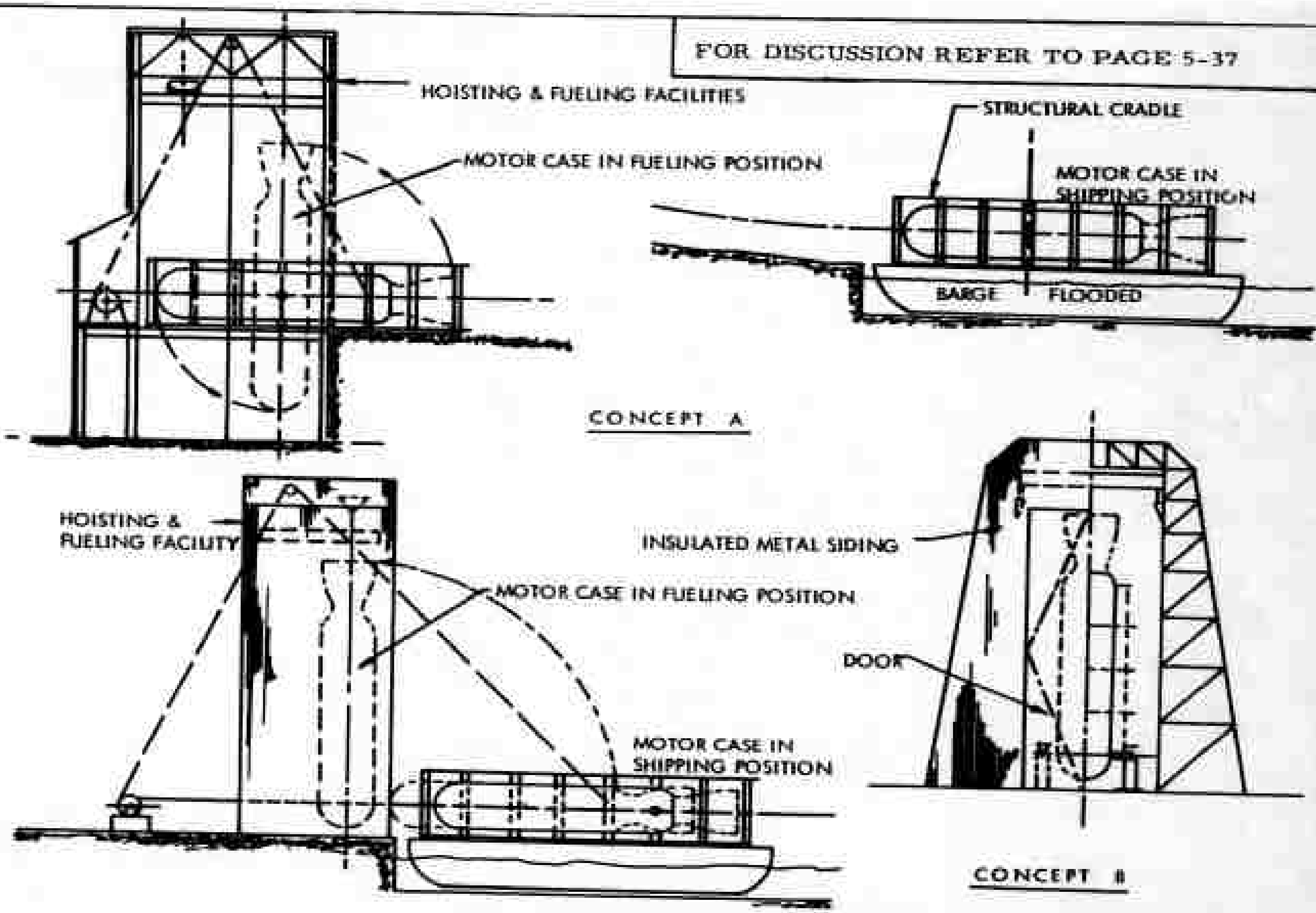


FIGURE 5-29
MOTOR MANUFACTURING FACILITY
(SUPPLIED BY KAISER INDUSTRIES CORP.)

FOR DISCUSSION REFER TO PAGE 5-37

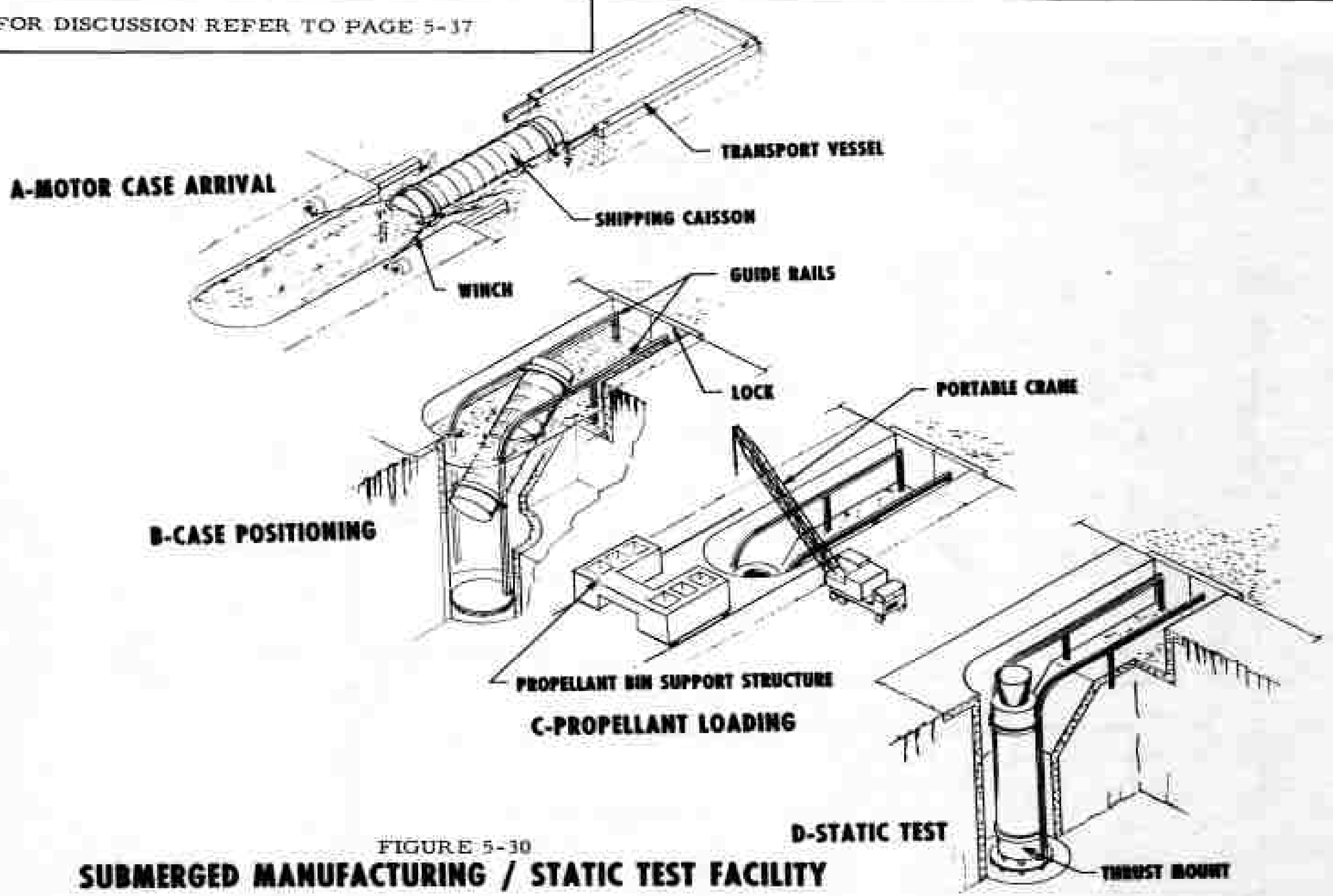
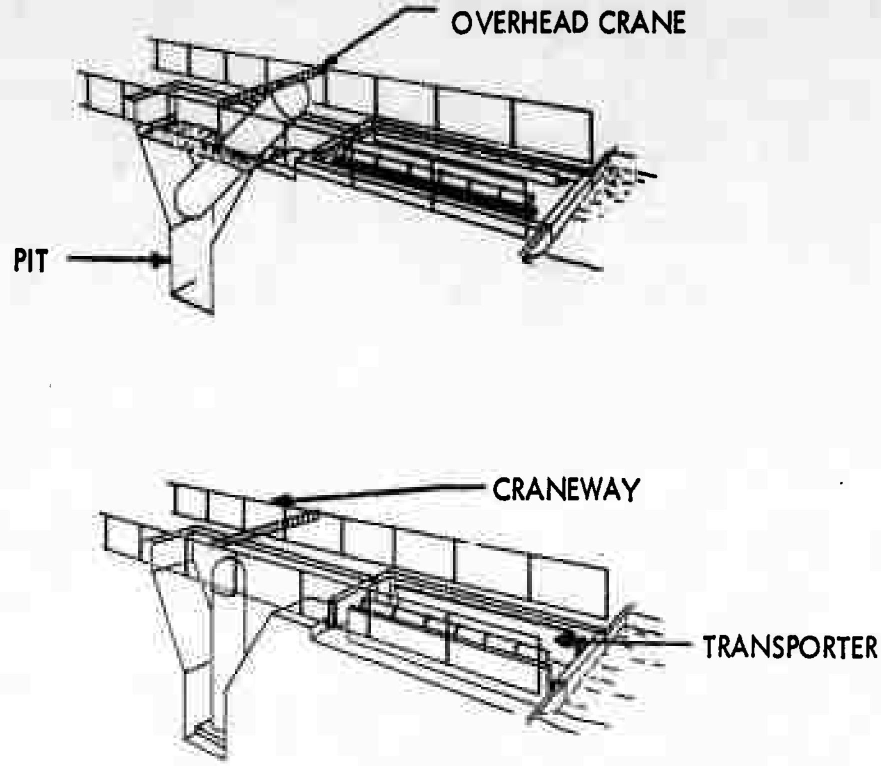
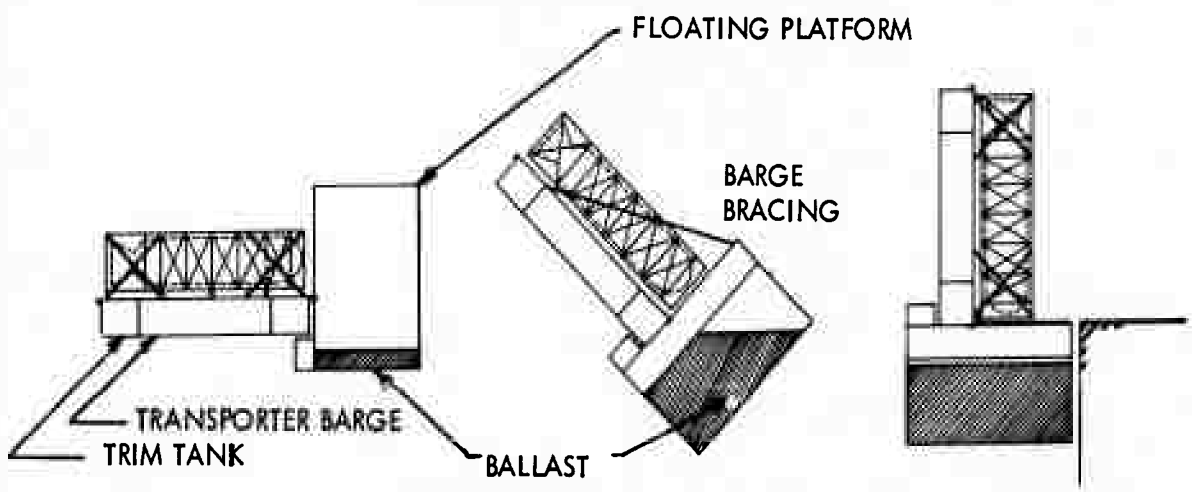


FIGURE 5-30
SUBMERGED MANUFACTURING / STATIC TEST FACILITY

FOR DISCUSSION REFER TO PAGE 5-38



CONCEPT A
(SUPPLIED BY FREDRICK R. HARRIS INC.)

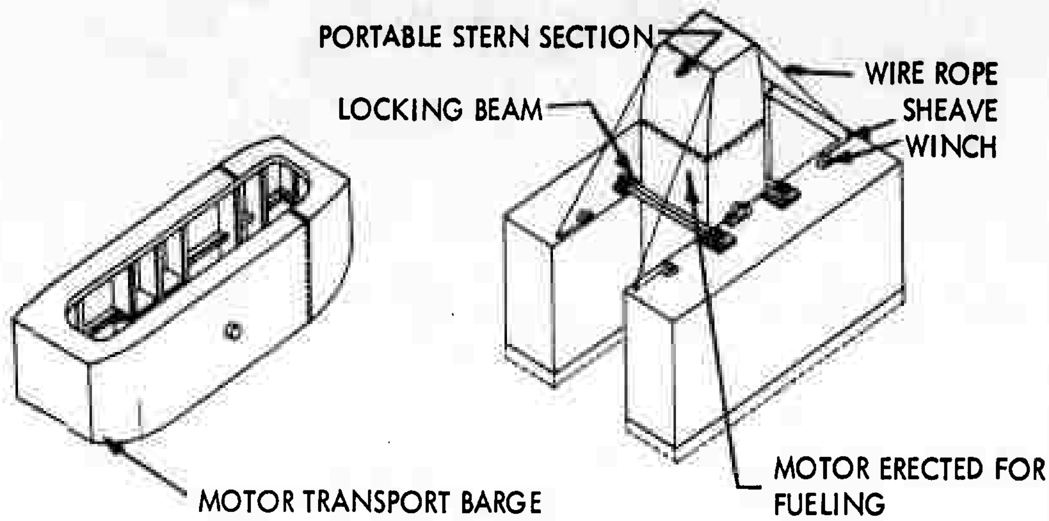


CONCEPT B
(SUPPLIED BY NEW YORK SHIPBUILDING CORP.)

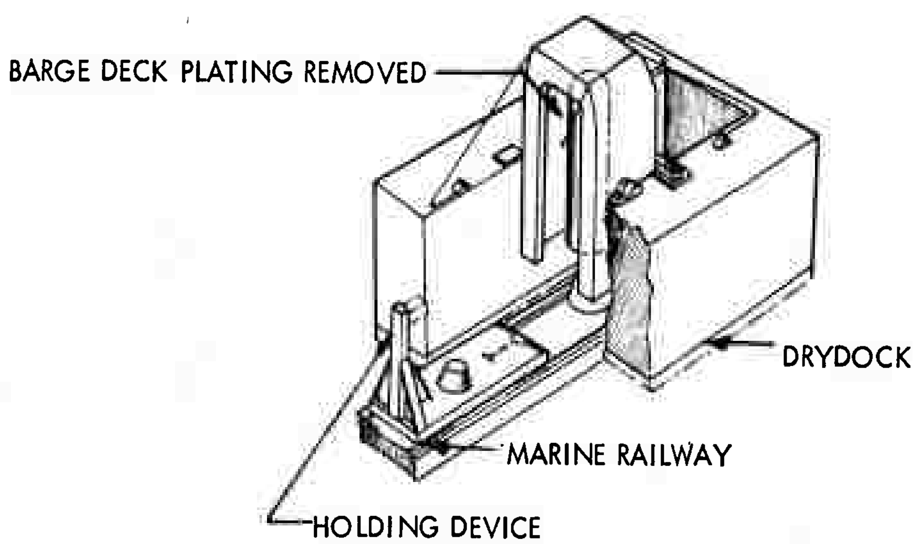
FIGURE 5-31

MANUFACTURING/STATIC TEST FACILITY (WET CONCEPTS)

FOR DISCUSSION REFER TO PAGE 5-40



A. MOTOR MANUFACTURING USING A FLOATING DRYDOCK



B. MOTOR ERECTION USING A FLOATING DRYDOCK AND A MARINE RAILWAY

FIGURE 5-32

MOTOR MANUFACTURING & ERECTION
(SUPPLIED BY NEW YORK SHIPBUILDING CORP.)

FOR DISCUSSION REFER TO PAGE 5-42

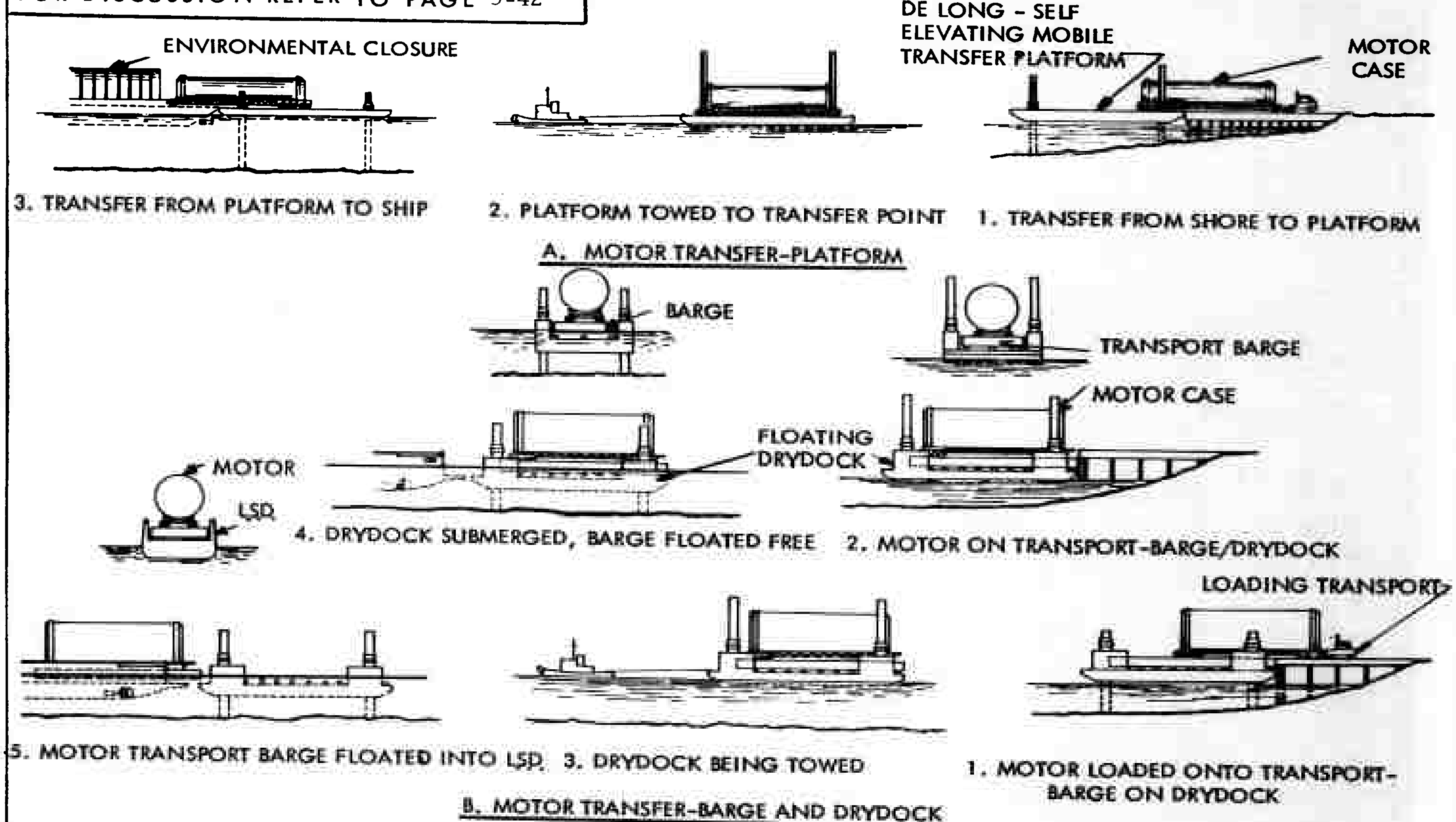
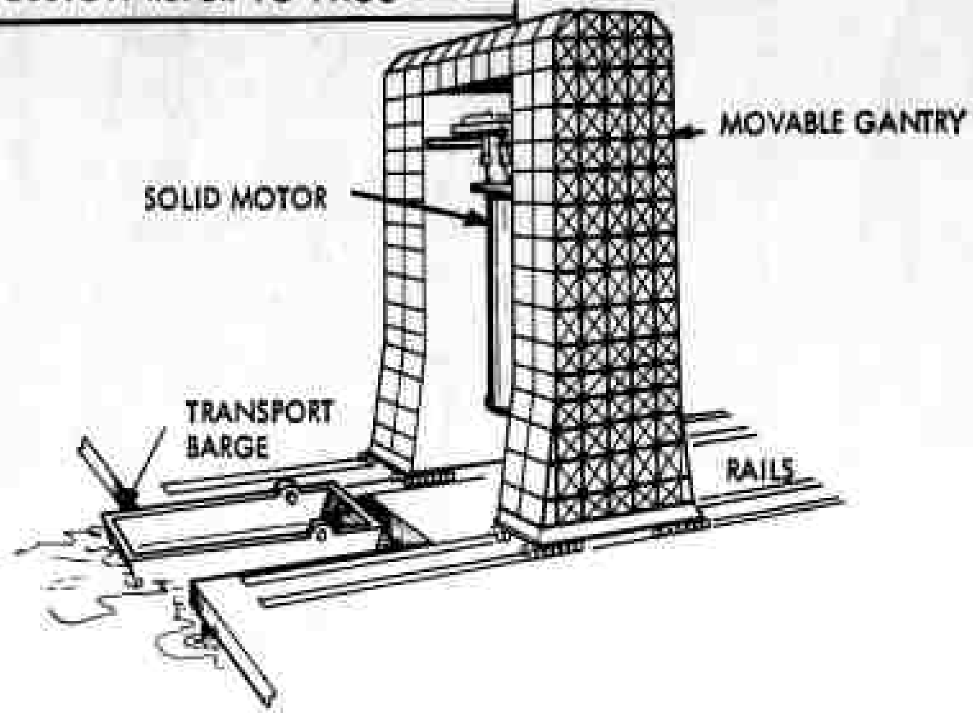


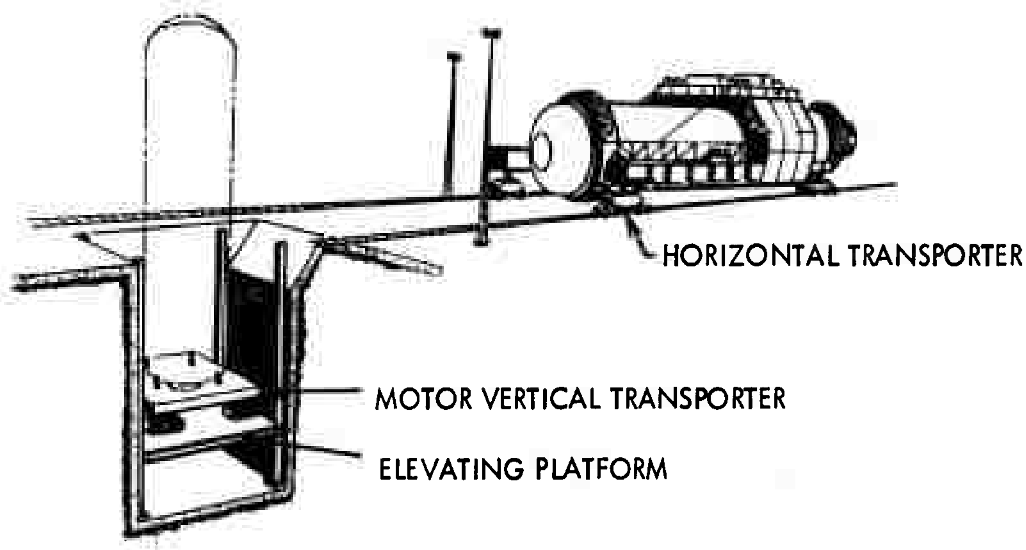
FIGURE 5-33

MOTOR LOADING AND TRANSPORT
(SUPPLIED BY THE DE LONG CORP.)

FOR DISCUSSION REFER TO PAGE 5-43



A. GANTRY CONCEPT



B. ERECTION PIT CONCEPT

FIGURE 5-34
OFFLOADING AND MOTOR ERECTION

FOR DISCUSSION
REFER TO PAGE 5-43

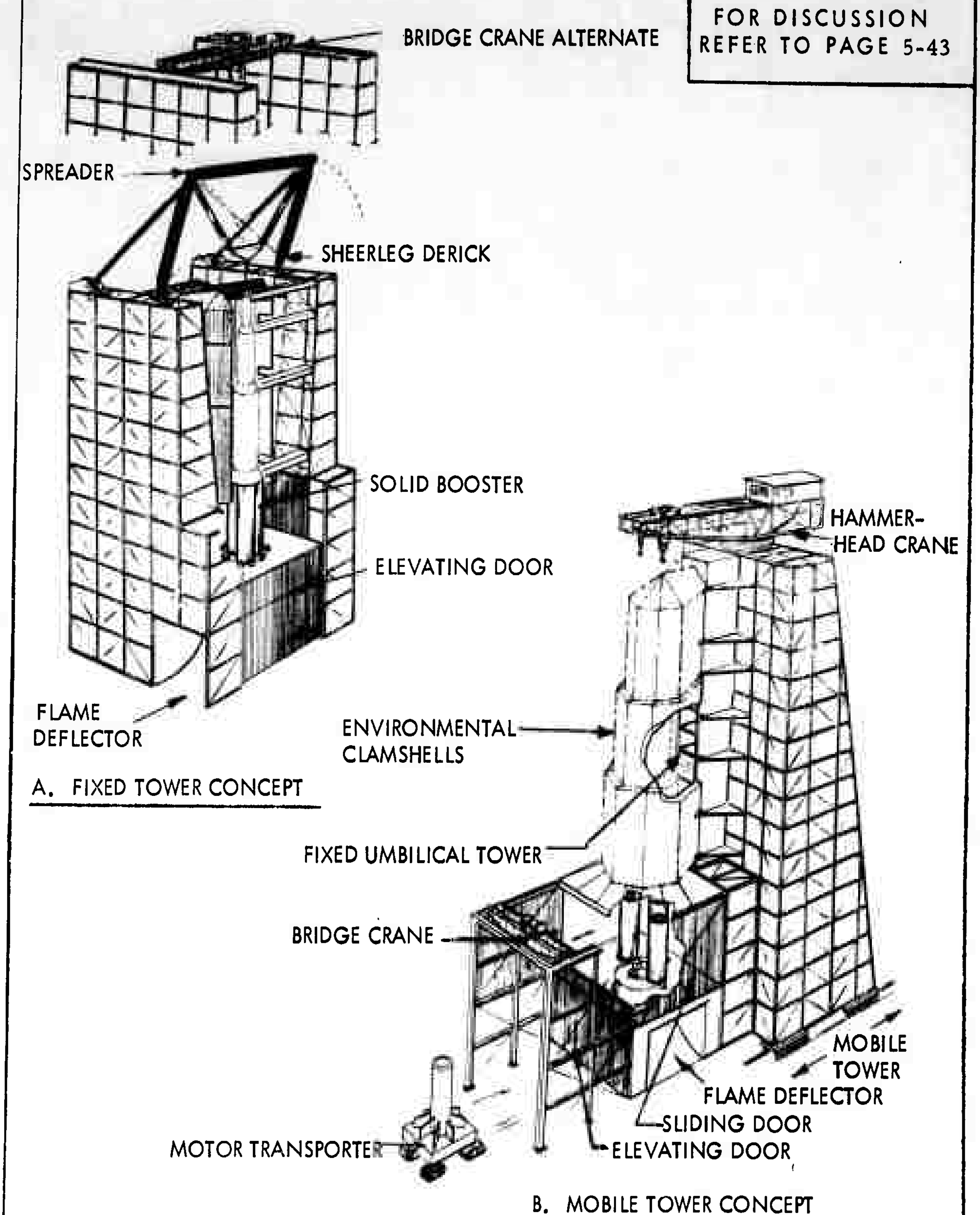


FIGURE 5-35
ON PAD ASSEMBLY

FOR DISCUSSION REFER TO PAGE 5-44

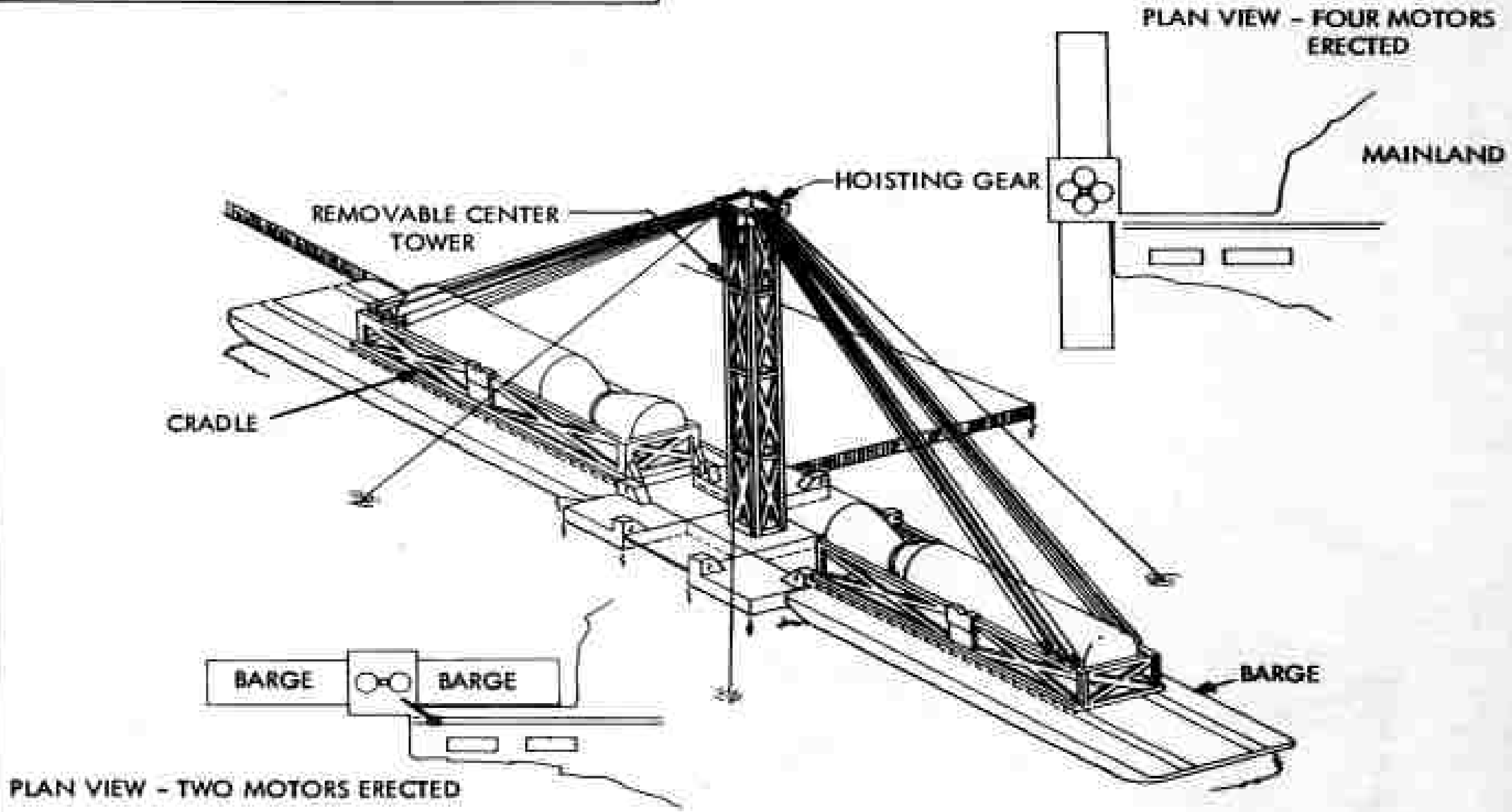


FIGURE 5-36
ON PAD BOOSTER ERECTION
(SUPPLIED BY TODD SHIPYARDS CORP.)

FOR DISCUSSION
REFER TO PAGE 5-45

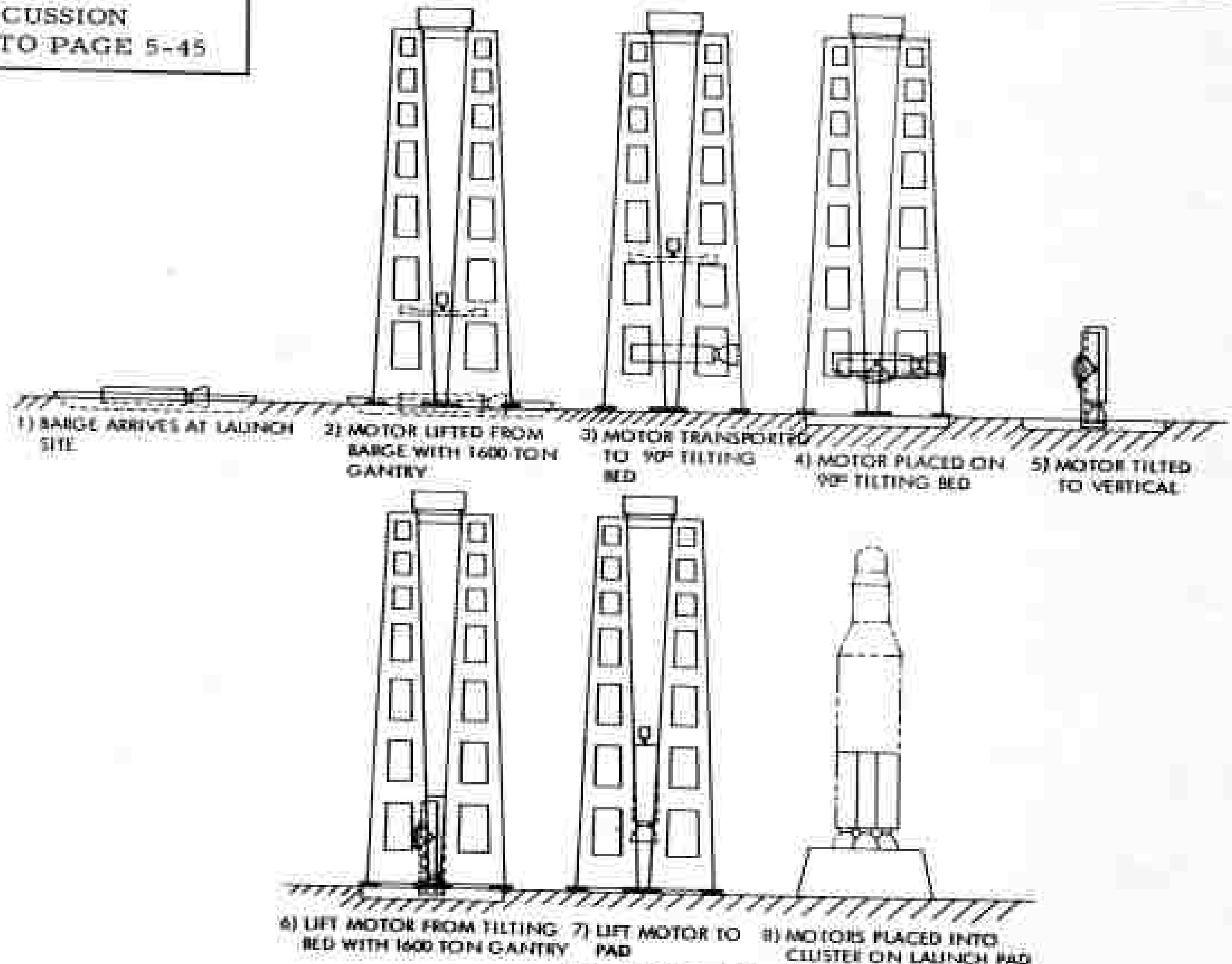


FIGURE 5-37
ON-PAD VEHICLE ASSEMBLY
(SUPPLIED BY MORGAN ENGINEERING CO.)

FOR DISCUSSION REFER TO PAGE 5-45

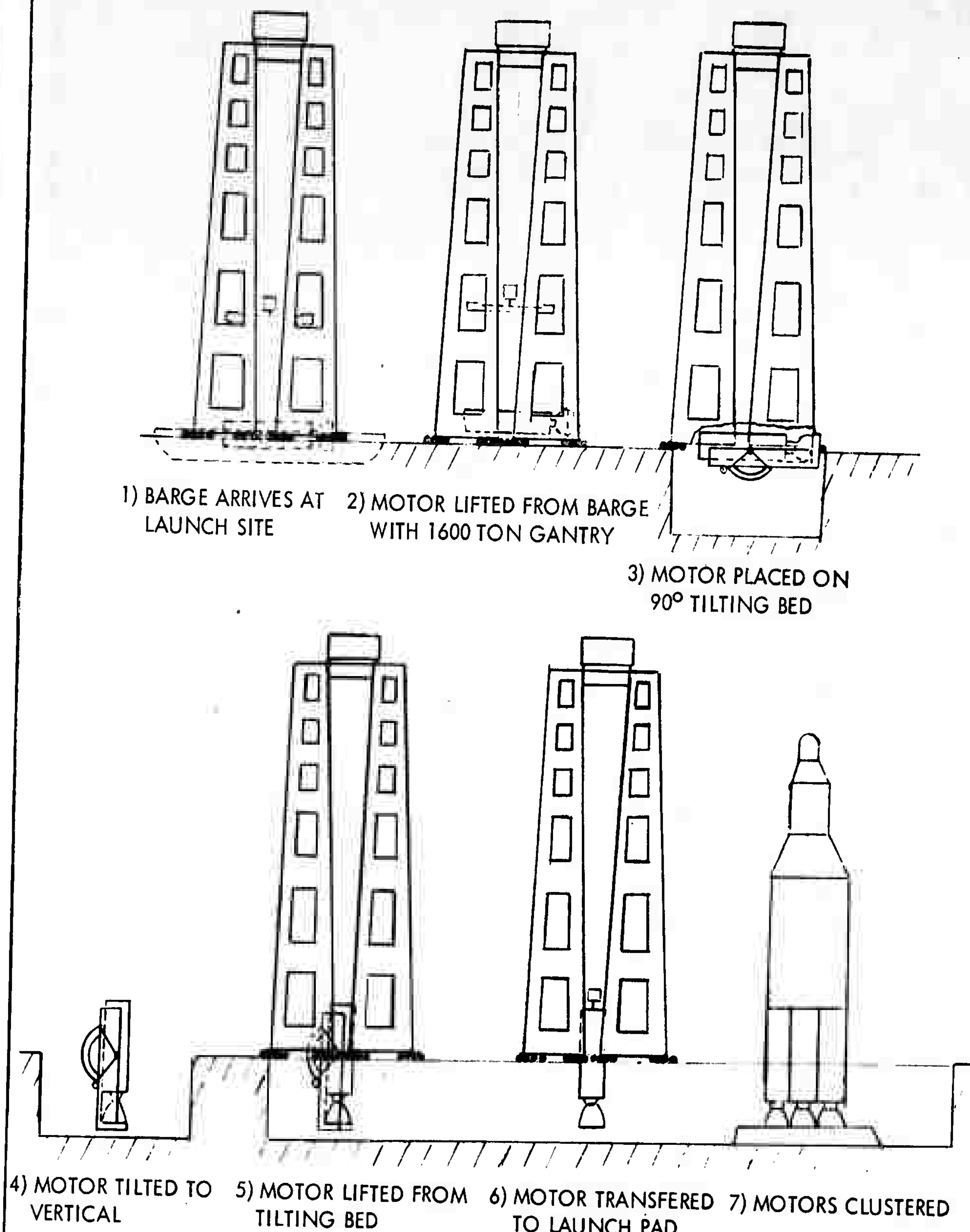


FIGURE 5-38
ON PAD VEHICLE ASSEMBLY - PIT METHOD
(SUPPLIED BY MORGAN ENGINEERING CO.)

FOR DISCUSSION REFER TO PAGE 5-45

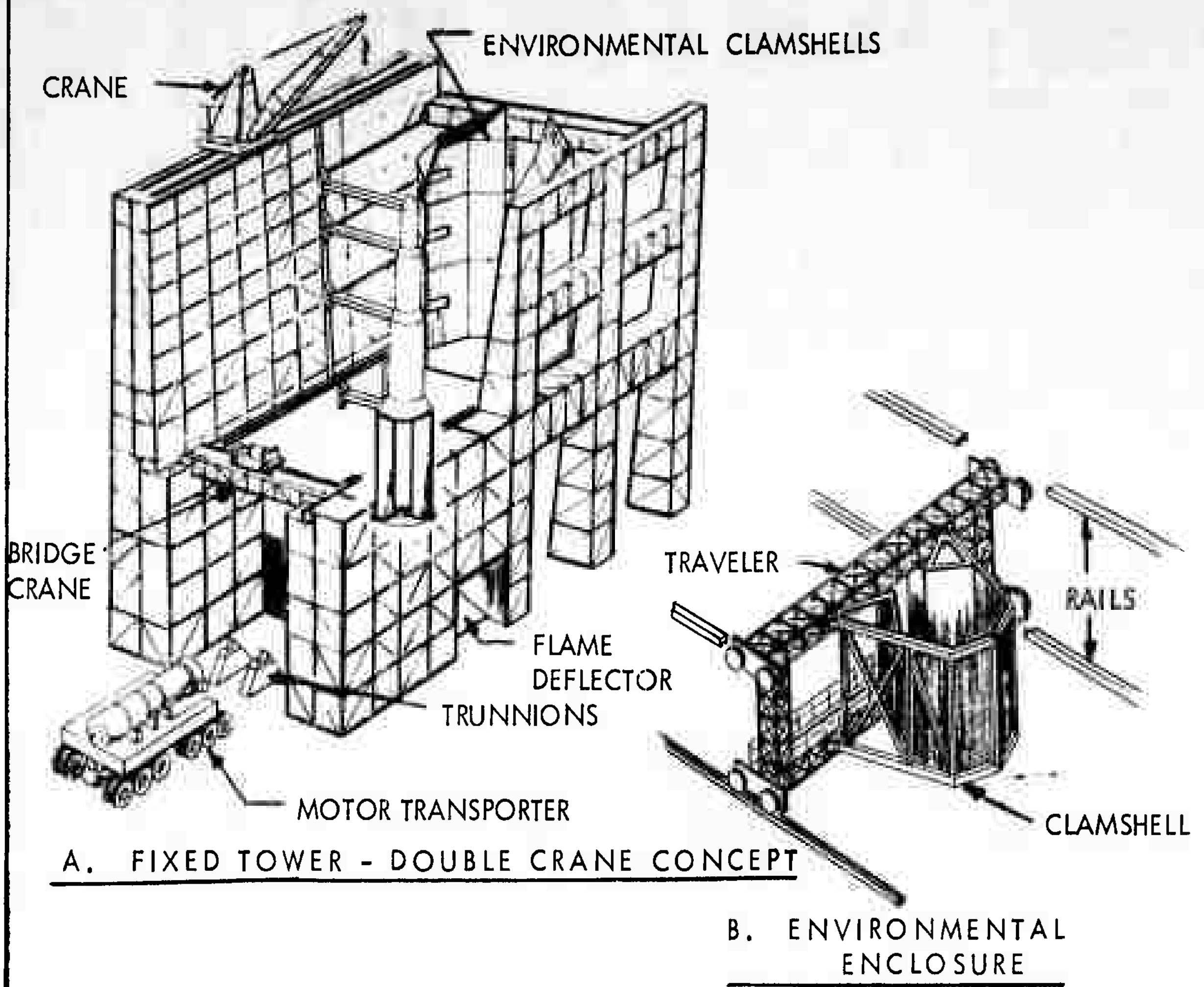


FIGURE 5-39

ON PAD ASSEMBLY

FOR DISCUSSION REFER TO PAGE 5-45

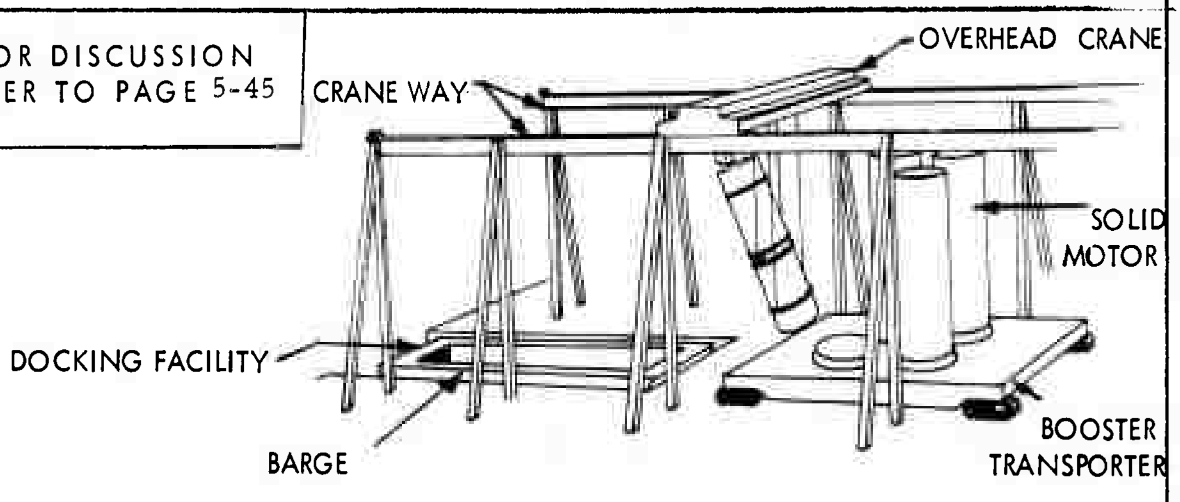


FIGURE 5-40
BOOSTER ASSEMBLY ON MOVABLE TRANSPORTER

FOR DISCUSSION REFER TO PAGE 5-46

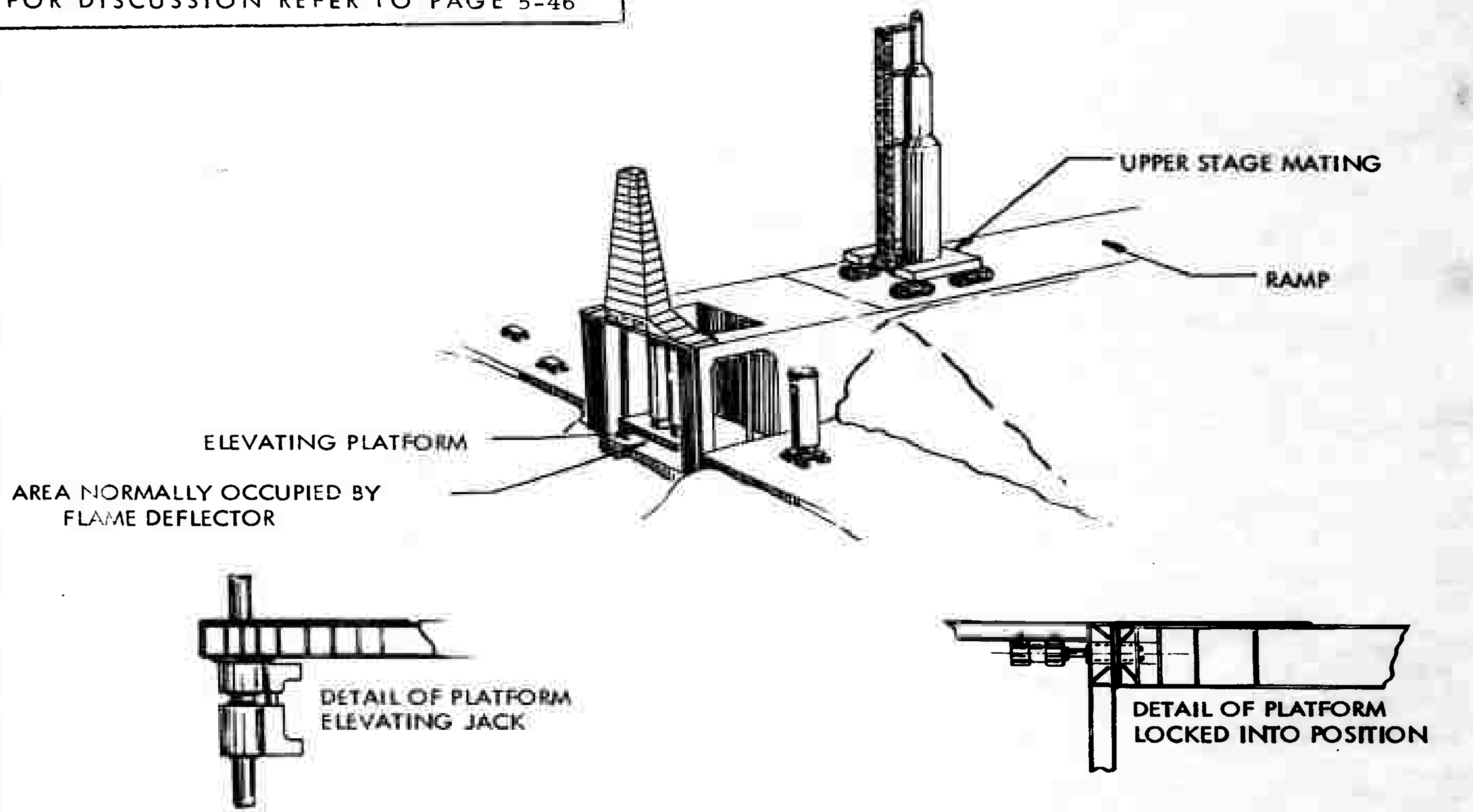


FIGURE 5-41

ON PAD BOOSTER ASSEMBLY - SEMI I.T.L. CONCEPT

FOR DISCUSSION REFER TO PAGE 5-47

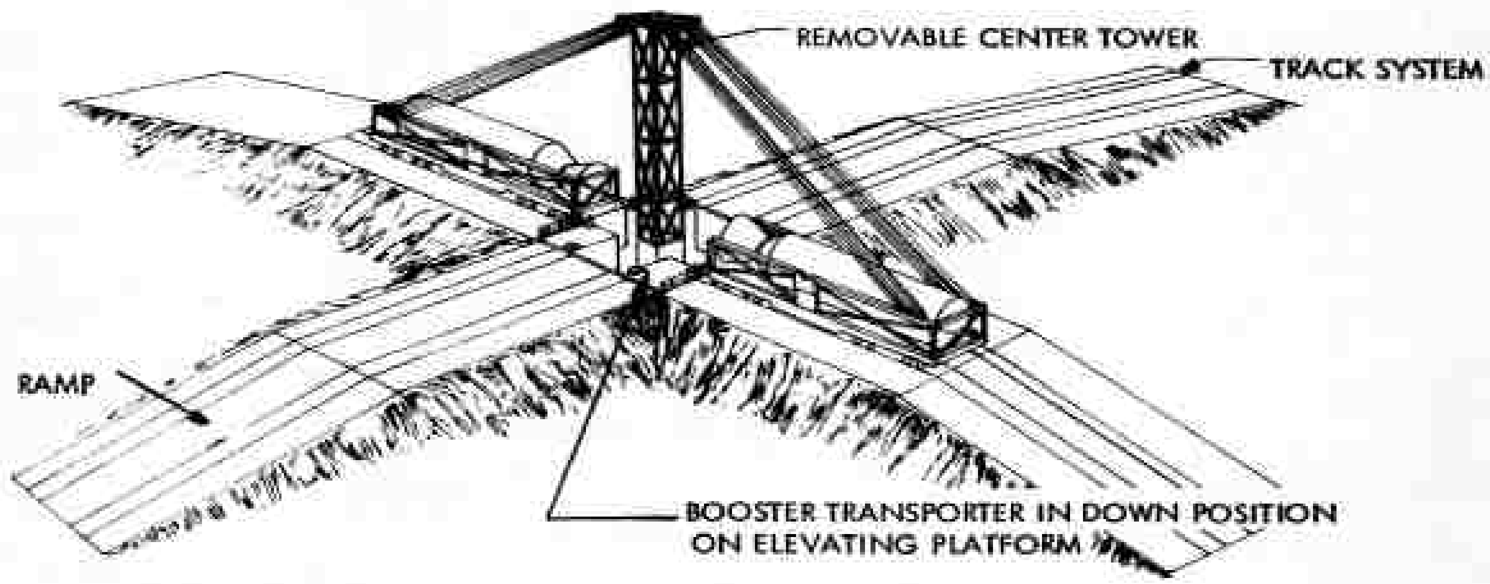


FIGURE 5-42
BOOSTER ASSEMBLY
(AMF LAND BASED I.T.L VERISON OF TODD SHIPYARDS CORP. CONCEPT)

FOR DISCUSSION REFER TO PAGE 5-48

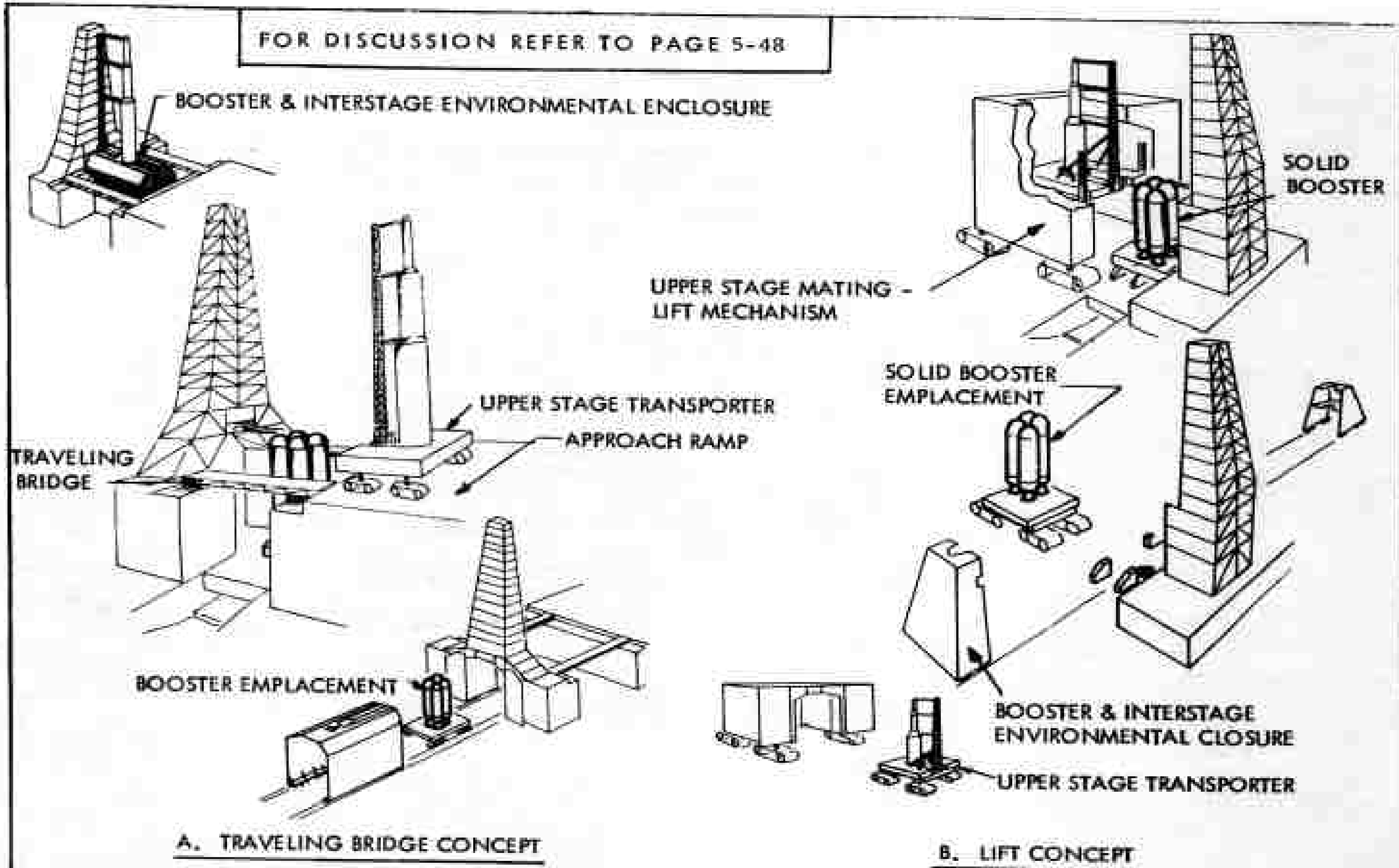


FIGURE 5-43
INTEGRATED TRANSFER LAUNCH SYSTEM CONCEPTS

SECTION 6
AREAS OF ACTIVITY AND FUNCTIONAL REQUIREMENTS FOR SOLID ROCKET MOTORS

1. GENERAL

This section describes the method used to establish AGE requirements for the selection of applicable equipment to handle components of the solid propellant rocket motors under study. In the establishment of the component flow and handling requirements, AMF relied on its subcontractor, United Technology Center (UTC). UTC established all the functional requirements for the motors at the manufacturing, static test and launch facilities, as well as procedures for handling, inspection and assembly of these motors.

Establishment of the functional requirements proceeded as outlined below:

1) Definition of the over-all propulsion system for the particular solid motor under investigation.

2) Definition of the motor components.

3) Definition of the facilities necessary to support the component processing within the three major sites (Manufacturing, Static Test and Launch) which must be considered.

4) Establishment of criteria for AGE to accomplish the processing operations.

By categorizing the support requirements into related groups and analyzing the results for desirable applications, firm decisions can be made for practical AGE design.

For the purpose of this study, three solid motor systems have been defined (120 and 156-inch segmented and 260-inch unitized). The areas of activity and specific actions and/or functions have been determined for both segmented and unitized motors, and are as follows:

<u>Motor Manufacturing Site.</u>

1) Inert Hardware Receiving, Inspection and Distribution
2) Inert Hardware Preparation

3) Propellant Casting and Curing
4) Casting Equipment Stripping and Component Inspection
5) Post Casting Inspection
6) Storage (Segments or Unitized Motors)
7) Igniter Sub Assembly and Inspection
8) Igniter Storage
9) Nozzle-TVC Assembly and Inspection
10) Nozzle-TVC Functional Checkout
11) Nozzle-TVC Storage, Packaging and Shipping
12) Pyrotechnic-Systems Receiving, Inspection and Shipping
13) Pyrotechnic-Systems Storage
14) Packaging and Shipping
    a) Receiving and Inspection from Storage
    b) Packaging
    c) On Loading to Prime Transporter

Static Test Site.

1) Receiving, Inspection, Sub-Assembly and Distribution
2) Storage and Conditioning (Segments or Unitized Motors)
3) Igniter Storage and Conditioning
4) Pyrotechnic Receiving, Inspection and Storage
5) Maintenance, Inspection Sub-Assembly and Storage
6) Static Test
    a) Vertical Test Bay
        (1) Motor Assembly
        (2) Static Checkout
        (3) Test
        (4) Disassembly
        (5) Distribution of Parts to Maintenance Facility
    b) Horizontal Test Bay
        (1) Motor Assembly
        (2) Static Checkout
        (3) Test
        (4) Disassembly
        (5) Distribution of Parts to Maintenance Facility

Launch Site.

1) Receiving, Inspection Sub-Assembly and Distribution
2) Storage and Conditioning (Segments or Unitized Motors)
3) Igniter Storage and Conditioning
4) Pyrotechnic Receiving, Inspection and Storage

5) Maintenance, Inspection, Sub Assembly and Storage
6) Motor and Vehicle Assembly
   a) Integrated Transfer and Launch Technique
      (1) Solid Motor Assembly
      (2) Launch Pad Operations
   b) Universal Launch Pad Technique
      (1) Launch Pad Operations

A complete discussion of the areas of activity, functional requirements, and suggested AGE can be found as follows:

120/156-Inch Segmented Motors - Pages 6-45 through 6-88 of this section.
260-Inch Unitized Motors - Pages 6-89 through 6-124 of this section.

NOTE 1. Facility Design is not part of the scope of this effort. However, it should be pointed out that facilities must be designed with quantity-distance spacing in mind (refer to Section 4). Moreover, it is emphasized that all facilities containing solid propellant will require environmental control.

NOTE 2. Since many of the facilities and the associated equipment at the sites are similar, close attention should be given to the choice of equipment design and techniques involved to permit standardization wherever possible.

a. Description of Rocket Motor Designs.

(1) General.

(a) 120 and 156-Inch Segmented Motors.

The design of either a 120-inch or a 156-inch diameter, solid-propellant, segmented rocket motor depends greatly on specific mission requirements and vehicle configuration. Since both mission requirements and vehicle configuration definitions are beyond the scope of this study, the subject motor designs discussed here reflect only a general motor configuration and may vary depending upon a specific use in a defined vehicle. The number of segments, propellant grain configuration, igniter motor size, location, size and number of thrust termination ports, nozzle type and size, and configuration of thrust vector control system (including tankage design) are possible variations to the motor designs described herein.

The structural attachments which may be required for use with the subject motors are also dependent on a particular vehicle configuration. Possible multistage vehicle configurations can include solid-propellant rocket motors arranged either in tandem with other stages or in clusters. Since the configuration of the structural attachments used in these different vehicles will vary, no attempt will be made to describe these components; however, these attachments would consist of the following:

1) Nose Cone
2) Interstage skirts and fairing
3) Attachment rings and brackets
4) Base heating shields and cowlings
5) Clustering Structures

The design of the 120-inch and 156-inch diameter segmented rocket motors selected for this study are shown in Figure 6-1, page 6-24 and Figure 6-2, page 6-25, respectively, and include the following:

1) Motor Case Assembly
2) Nozzle and Thrust Vector Control (TVC) System
3) Ignition System
4) Thrust Termination System
5) Destruct System

(b) <u>260-Inch Unitized Motors.</u>

The specific design of a 260-inch diameter, unitized, solid-propellant rocket motor will depend on the vehicle configuration in which it is to be used and the mission requirements. Several possible vehicle configurations which could utilize 260-inch diameter motors in clusters were investigated. A motor design was established which could, in a cluster of seven, be used as the first stage for boosting a one-half million pound payload to escape. It is believed, even though minor modifications to the selected motor design would be required for different vehicle configurations, AGE requirements would remain basically the same for all missions. Design variables for the use of clustered motors are interstage skirts, fairings, clustering structure, vehicle configuration, and mission requirements.

Figures 5-10 through 5-13, pages 5-22 through 5-25 and Figures 5-35, through 5-43, pages 5-69 through 5-76 show methods of assembling several motors (either segmented or unitized) fo form a first stage booster. Methods of clustering projected range from using vertical transporters which then become part of the Launch Pad structure to stationary gantries at the launch pad.

The actual methods of attaching motors to each other will vary with the particular vehicle to be considered and was considered to be beyond the scope of this study. Interested persons are referred to "Technical Documentary Report No. SSD-TDR-62-144," titled "Study of Large Launch Vehicles Using Solid First Stages" by the Boeing Company.

Several nozzle and thrust vector control (TVC) system designs have been considered for use with these large-size motors. These include fluid or hot gas injection and jet tab insertion into both straight and canted nozzle exhaust streams, and hinged and gimballed nozzles. Present state-of-the-art for thrust vector control on large solid-propellant motors (120-inch diameter motor) has been accomplished by use of fluid injection into the nozzle exhaust stream. Hinged and gimballed nozzles of the size required for a 260-inch diameter motor would require considerable development and could possibly complicate the design of clustering structures.

During the course of this study, insufficient data was available on the gimballed nozzle, jet tabs and hot gas injection TVC systems. Preliminary data indicates that the gimballed nozzle technique would be similar to that used for the Minuteman system. The Jet tab technique is simply a mechanical system designed to insert tabs into the exhaust stream. It appears, at present, that hydraulic systems will be used to actuate either the gimballed nozzle or jet tab TVC system. The hot gas system is similar to the liquid injection system except that hot gas rather than liquid is used as the injection medium. The type of actuation system will affect AGE with regard to installation, envelope dimensions, package weight, servicing and checkout provisions for the particular Nozzle TVC application considered.

Since the use of liquid injection for TVC was more advanced at the time of the publication of this report, this system was selected for study.

The selection and location of the pyrogen ignition system shown in this study is representative of the present state-of-the-art used for igniting large solid-propellant motors. Presently under development is the application of the pyrogen igniter to aft end ignition. Also undergoing extensive development is the hypergolic ignition system which could be applied to either forward or aft end ignition.

The 260-inch diameter motor design selected for this study is shown in Figure 6-3, page 6-26 and includes the following systems and assemblies:

1) Motor Case Assembly
2) Nozzle Assembly and Thrust Vector Control System
3) Ignition System
4) Destruct System

NOTE: No requirement for thrust termination of the 260-inch unitized motor has been considered up to the time of publication of this report.

(2) Motor Case Assembly.

(a) 120 and 156-Inch Segmented Motor.

The motor case assembly consists of segments and forward and aft closures. Segments and closures are joined together by clevis and pin type joints. (See Figure 6-4, page 6-27). Motor joint design could vary from that shown (i. e., clevis and lock ring, clevis and bolt). Joint pins are secured in place with flexible retaining bands which form a 360° wrap around the case joints. A segment consists of a cylindrical steel case with internal insulation and is cast with solid propellant. The forward and aft closures consist of cylindrical steel cases with formed hemispherical heads, internal insulation and solid propellant. The forward closure incorporates provisions for housing an igniter motor assembly and ports for thrust termination.

A forward stub-skirt with flange is included for attachment of interstaging skirt, attachment ring, or motor nose fairing, as required. The aft closure incorporates provisions for attachment of the motor nozzle. A rear stub-skirt is provided for attachment of the interstaging skirt, attachment ring, TVC tankage and pressure regulator assembly, heat shield, and cowling.

(b) 260-Inch Unitized Motor.

The motor case assembly consists of a unitized cylindrical steel case with formed hemispherical forward and aft heads (closures) and flange stub skirts. (See Figure 6-5, page 6-28). The case includes internal wall insulation with liner into which the solid propellant is cast.

The aft skirt extension provides for support and attachment of the TVC assembly and for motor handling. The forward stub skirt and aft skirt extension provide for attachment of the following:

1) Interstaging skirt or fairing
2) Attachment Rings
3) Base Heat Shield and Cowlings

The forward closure includes provisions for housing the ignition system. The aft closure incorporates indexing and attachment provisions for the motor nozzle assembly. Three reinforced ring ridges could be provided on the outside diameter of the case for handling, equipment indexing, bearing, and attachment to the motor case.

(3) Typical Nozzle and Thrust Vector Control (TVC) System.

(a) 120 and 156-Inch Segmented Motors.

The nozzle and liquid injection thrust vector control system consists of a motor nozzle-TVC subassembly, and a tankage and pressure regulator assembly. (See Figures 6-1 and 6-2, pages 6-24 and 6-25). TVC subassembly consists of the motor nozzle, injectant manifold (part of the nozzle), injector valves, hydraulic pilot valves, hydraulic control system and power supply, and electronic control subsystem and power supply. The tankage and pressure regulator assembly consists of a fluid tank, pressurization tanks, pressure regulator system, and liquid injectant feed line. The configuration of this assembly could vary from that shown depending on the motor and vehicle design requirements. An alternate configuration which could be used would be cylindrical tanks that are mounted parallel to the motor longitudinal axis. (For a further discussion of thrust vector control system, refer to paragraph (b) Pages 6-4 and 6-5).

(b) 260-Inch Unitized Motor.

The nozzle assembly consists of the nozzle and exit cone extension. The nozzle is made up of a steel case with an internal graphite and phenolic throat and exit insulation. Provisions for housing and attaching thrust vector control components are also incorporated. The exit cone extension provides for nozzle expansion. The configuration of this assembly could vary from that shown depending on specific motor and vehicle design requirements.

The TVC system consists of a tankage assembly, injectant feed line assembly, (see Figure 6-3, page 6-26), and the following additional electromechanical components:

1) Injector Valves
2) Hydraulic pilot valves
3) Hydraulic control system and power supply
4) Electronic control subsystem and power supply

They are assembled to the nozzle and form the nozzle TVC subassembly.

The tankage assembly includes the nose cone, pressurization tank, interstage and pressure regulator assembly, injectant tank assembly, support skirt and bracket, and tankage attach bracket assemblies. The injectant feed line assembly includes filler line and feed line with bellow-type gimbal expansion joints. (For a further discussion of thrust vector control refer to Paragraph (b), pages 6-4 and 6-5).

(4) Ignition System (All Motors).

The ignition system consists of an igniter motor and a safe and arm (S&A) assembly. (See Figures 6-1 and 6-3, pages 6-24 and 6-26). The igniter motor is a solid propellant cartridge housed in a steel case. The S&A assembly consists of a housing, electrical ignition squibs, and a pellet basket containing explosive pellets.

(5) Thrust Termination System (120 and 156-Inch Motors).

The thrust termination system includes port covers and stacks, safe and arm assembly, detonating fuse transfer harness (see Figures 6-1 and 6-2, pages 6-24 and 6-25) and shaped charges. The S&A assembly consists of a housing and detonator. The transfer harness consists of a high explosive encased in flexible plastic tubing which connects the S&A assembly to the shaped charge. The shaped charge is a high explosive encased in metal tubes and clipped to the port covers.

(6) Destruct System (All Motors).

The destruct system consists of a safe and arm (S&A) assembly, detonating fuse transfer and jumper harnesses, and shaped charges. The S&A assembly is identical to that used in the thrust termination system.

The transfer and jumper harnesses are also the same as those used in the thrust termination system except that the jumper harness connects and provides continuity of the detonation shock between sections of the shaped charge. The shaped charge consists of a high explosive encased in sections of metal tubing which are clipped to the motor case segments parallel to the motor axis.

b. Motor Assembly.

(1) Description and Physical Properties - Approximate.

	120-in. Segment	156-in. Segment	120-in. Forward Closure	156-in. Forward Closure	120-in. Aft Closure	156-in. Aft Closure	260-in Unitized Motor
Figure No.	6-4	6-4	6-6	6-6	6-7	6-7	6-5
Page No.	6-27	6-27	6-29	6-29	6-30	6-30	6-28
Outside Dia. In.	120	156	120	156	120	156	260
Length-In.	130	288	175	90	65	175	1400
Weight-lbs.	80,000	270,000	136,000	35,000	28,000	136,000	3,157,000

(2) Propellant Classification.

The explosive classification of the composite, single base propellant will be Class "B" as described in the Interstate Commerce Commission Regulation Tarriff No. 13.

(3) Environmental Protection.

The temperature and humidity of the solid propellant throughout handling, storage, and inspection should be maintained within 60 to 90°F at a relative humidity not to exceed 50 percent.

Before static testing or launching, the segments or motors should be controlled within $\pm$ 5°F to insure uniform performance (control of thrust level and burning duration) of motors tested individually or in multiples. A one degree (1°F) change in temperature will result in approximately a 0.15 percent change in thrust level. Any temperature between 60 and 90°F may be selected as the prefire conditioning temperature.

Adequate protection against corrosion, deterioration and physical damage during handling and shipping shall be in accordance with Federal Standard No. 102, level "C".

(4) Support Attach Points and Allowable Loading.

(a) 120 and 156-Inch Segmented Motors.

For the segments, internal rounding-handling rings (Figure 6-8, page 6-31) will be engaged with the attach joints to distribute handling loads uniformly and to maintain the geometry of the attach joints. Support and attach points for all handling will be through these rings. Vertical lifting can be accomplished through either the fore or aft ring. Horizontal lifting requires attachment to both fore and aft rings.

During forward and aft closure handling, an internal rounding-handling ring (Figure 6-8, page 6-31) will be engaged into the attach joint and a handling ring will be attached to the stub skirt. Both rings will distribute handling loads uniformly and maintain the geometry of the attach joint and skirt. Support attach points for all handling should be through these rings. Vertical lifting can be accomplished either by the joint or by the sub skirt handling rings, whereas horizontal lifting will require attachment to both attach joint and skirt handling rings.

Transporting and storing may be accomplished in either a vertical or horizontal attitude. The envelope clearance dimensions for a given route will dictate the transportation attitude. Slump characteristics of the propellant grain may dictate the preferable orientation and may require supplemental grain support. Maximum allowable shock loads should not exceed 10 g's in any plane.

A comparison of the allowable and critical bending moments for a seven segment 120-inch and 156-inch diameter motor during tilting or erection operations for a fully assembled motor is as follows:

	BENDING MOMENT, IN - LBS			
	Allowable	Case Thickness	Case Material	Actual
120-inch diameter motor (7 segments)	271,000,000	.355 in.	"Ladish" D-6AC	63,750,000
156-inch diameter motor (7 segments)	425,000,000	.406 in.	Ultra High Strength Steel	423,000,000

For a shorter length motor, the actual bending moment would be reduced.

(b) 260-Inch Unitized Motor.

Support and attach points for handling, transporting and storage could be accomplished through the handling-attach ridges (see Figure 6-5, page 6-28) at stations 420.0, 705.0 and 990.0 and/or in combination with fore and/or aft skirts as required. A comparison of the allowable and actual bending moments for the various combinations of handling-attach ridges and skirts is presented below.

	BENDING MOMENT, IN. - LBS			
Attach Point Combination	Allowable	Case Thickness	Case Material	Actual
Forward and Aft Skirt	215,000,000	0.70 in.	"Ladish" D-6AC Ultra High Strength Steel	488,000,000
Sta. 420 and Aft Skirt	215,000,000			262,000,000
Sta. 705 and Aft Skirt	215,000,000			142,000,000
Sta. 420 and Sta. 990	215,000,000			101,500,000

Maximum allowable shock loads should not exceed 10 g's in any plane.

(5) Inspection (120, 156 and 260-Inch Motors).

(a) Visual.

All exposed internal and external surfaces should be inspected visually for in-transit damage (i.e., scratches, dents, cracks, corrosion and grain erosion). The extent of damage to the component and the effect on its performance should be evaluated by a Material Review Board.

(b) Physical.

Propellant grain should be given a complete profile inspection to a close tolerance (plus or minus 1/10 of an inch - typical). Areas to be measured are: grain length, aft surface of grain with relation to the joint end of the case, grain bore diameters and straightness and, in the case of the 260-inch motor, its relation to forward and aft closure openings.

(c) Non-Destructive Testing.

Satisfactory bonding between case and insulation should be determined. Ultrasonics is one method which can be used. Internal cracks, voids, fissures, and porosity of grain may be determined by use of radiographic means. In addition, radiographic techniques may be used for determination of satisfactory bonding between case-insulation, insulation-liner, and liner-to-grain. This method, however, becomes more complicated and expensive with increasing propellant web thickness.

Any of the above defects should be analyzed and classed as critcal or non-critical depending upon mission requirements and allowable variation in motor performance.

(6) Checkout.

No leakage should be permitted at attachment joints of the assembled motor, igniter and thrust termination port attach bosses over a period of 30 minutes at an internal pressure (inert gas) of 70 psig.

c. 260-Inch Motor Aft Skirt Extension.

Figure 6-9, page 6-32 illustrates the configuration of the aft skirt extension and identifies its shape and attach areas.

(1) Physical Size and Weight.

1)	Outside diameter, inches	260
2)	Length, inches	48
3)	Weight, lbs.	6, 500

(2) Environmental Protection.

No special temperature or humidity control is required. Adequate protection should be provided against corrosion, deterioration, and physical damage during shipping and storage in accordance with Federal Standard No. 102, level "C". (These conditions are typical of most inert hardware and are referenced throughout this report). It should be noted that the envelope dimensions of this item precludes unrestricted shipment by rail and complicates shipment by truck.

(3) Support-Attach Points and Allowable Loading.

Support during horizontal handling, transporting and storage is accomplished through the forward and aft attach flanges; the inside of the skirt should be adequately blocked and braced to maintain the geometry (roundness) of the skirt. Vertical handling, transporting and storage may be accomplished through either the forward or aft attach flanges. The envelope clearance dimensions for a given transportation route will dictate the attitude of transport.

(4) Inspection.

(a) Visual.

All exposed surfaces should be inspected for in-transit damage (i.e., scratches, dents, cracks, corrosion, etc.). The extent of damage to the component and its effect on motor performance should be evaluated by a Material Review Board. (This inspection is typical of most inert hardware and is referenced throughout this report).

(b) Physical.

Dimensional tolerances of the skirt attach flange diameters, attach holes and TVC tank support bracket attach holes should be inspected for go-no-go condition.

d. 260-Inch Motor Nozzle Exit Cone Extension.

Figure 6-10, page 6-33 illustrates the exit cone extension and identifies its shape, attach areas, and components.

(1) Physical Size and Weight.

1)	Forward diameter, inches	210
2)	Aft diameter, inches	260
3)	Length, inches	120
4)	Weight, lbs.	10,000

(2) Environmental Protection.

Refer to paragraph c (2), page 6-12.

(3) Support-Attach Points and Allowable Loading.

Support and attachment for all horizontal handling, transporting, storage, etc. should be through the nozzle exit cone extension attach flange and the special support-attach points shown in Figure 6-10, page 6-33. Vertical handling, transporting, etc. may be accomplished through either the forward attach flange or aft attach points. A special attach shoulder on the forward flange may be used for cone-to-nozzle assembly.

Transporting and storing should be accomplished in the vertical attitude. Maximum allowable shock loads should not exceed 10 g's in any plane. Transportation by rail car and truck is limited by the dimensions of the unit. The transportation problem could be alleviated by sectionalizing the nozzle assembly. (NOTE: Due to the sizes and weights of the components being considered, air transportation has been ruled out as a prime transportation mode).

(4) Inspection.

(a) Visual.

Refer to paragraph (4) (a), page 6-13.

(b) Physical.

Dimensional tolerances of the nozzle at the throat, exit cone, and aft closure mating flange should be checked for a go-no-go condition.

e. Nozzle-TVC System.

Refer to paragraph (b), pages 6-4 and 6-5 for additional discussion.

(1) Nozzle-TVC Subassembly.

Figure 6-10, page 6-33 and Figure 6-11, page 6-34 illustrate a typical nozzle Liquid-Injection-TVC-System assembly configuration and identify shape, attach areas, and components.

(a) Physical Size and Weight.

	120-inch	156-inch	260-inch
Figure No.	6-11	6-11	6-10
Page No.	6-34	6-34	6-33
Forward diameter (flange) in.	60	85	140
Aft diameter, in.	110	156	210
Length, in.	140	170	210
Weight, lbs.	7, 500	20, 000	30, 000

NOTE: The dimensions shown for the 260-inch motor are critical for rail and truck transportation.

(b) Environmental Protection.

Refer to paragraph c (2), page 6-12.

(c) Support-Attach Points and Allowable Loading.

Transporting and storing may be accomplished in either the vertical or horizontal attitude. Maximum allowable shock loads should not exceed 10 g's axially and 3 g's transversely.

1) 120 and 156-Inch Motor Nozzle-TVC Support Attach Points. Support and attach points for all handling, transporting, storage, etc. should be through the nozzle-closure attach flange and the support attach points (Figure 6-11, page 6-34) just aft of the TVC injection valves, common to the nozzle exit cone case. The flange is a close tolerance, machined surface with through holes which may be used for attachment and support. The support attach points just aft of the TVC injection valves, common to the nozzle exit cone case may be used to support and lift the subassembly during handling, transporting, etc.

2) 260-Inch Motor Nozzle-TVC Support Attach Points. Support and attach points for all horizontal handling, transporting, storage, etc. shall be through the nozzle-closure attach flange and nozzle-exit cone extension

attach flange. Vertical handling, transporting, etc. may be through either the forward or aft attach flanges. Both flanges are close tolerance, machined surfaces with through holes which may be used for attach and support. A special attach shoulder on the forward flange may be used for nozzle to closure assembly.

(d) Inspection.

Refer to paragraph c (4), page 6-13.

(e) Checkout.

Figure 6-12, page 6-35 illustrates typical liquid injection TVC system flow and checkout requirements, instrumentation accuracies, and allowable tolerances for parameters requiring checkout.

(2) 120 and 156-Inch Motor Liquid Injection TVC Tankage and Pressure Regulator Assembly.

Figure 6-13, page 6-36 illustrates the tankage and pressure regulator assembly (120-inch and 156-inch) and identifies typical shapes, attach areas, and components.

(a) Physical Size and Weight.

	120-inch	156-inch
Outside Diameter, in.	119	154
Length, in.	70	85
Weight (dry), lbs.	7,000	15,000

(b) Environmental Protection.

Refer to paragraph c (2), page 6-12.

(c) Support-Attach Points and Allowable Loading.

Support and attach points for all handling, transporting, and storage will be accomplished through the mounting brackets.

(d) Visual Inspection.

Refer to paragraph (4) (a), page 6-13.

(e) Checkout.

1) Pneumatic. No leakage shall be permitted at connections of the assembled tankage and pressure regulator system over a period of 30 minutes at an internal pressure (inert gas) of 150 psig.

2) Functional. Refer to Figure 6-12, page 6-35.

(3) 260-Inch Motor Liquid Injection Thrust Vector Control System.

Figure 6-3, page 6-26.

(a) Pressurization Tank, Injectant Tank Assembly and Injectant Feed Line Assembly.

Figures 6-14, page 6-37 and Figure 6-15, page 6-38 illustrate typical configurations, shape and attach areas for the above components. (See also Figure 6-16, page 6-39).

1. Physical Size and Weight.

	Press. Tank	Injectant Tank Assy	*Injectant Feed Line Assy
Outside diameter, in.	64	68	36
Length, in.	312	621	250
Weight, lbs. (Dry)	17,000	8,400	2,595

* The Injectant Feed Line Assembly consists of three parts and should be handled in the disassembled condition. See Figure 6-3, page 6-26 for physical sizes and weights of of separate parts.

2. Environmental Protection.

Refer to paragraph c (2), page 6-12.

3. Support-Attach Points and Allowable Loading.

Support and attach points for all handling, transporting, storage, etc. shall be accomplished through attach flanges by handling equipment attachment in the areas or adjacent to the flanges. A comparison of the allowable and actual bending moment for the empty pressurization tank, injectant tank assembly, and pressurization-injectant tank assembly during tilting or erection operations is shown below (handling at forward and aft ends of tank). Material considered is 0.25 inch thick 410 Stainless Steel.

	BENDING MOMENT, IN-LBS.	
	Allowable	Actual
Presurization Tank	109,000,000	668,000
Injectant Tank Assembly	69,000,000	611,000
Pressurization-Injectant Tank Assembly	69,000,000	3,050,000

4. Inspection.

1) Visual. Refer to paragraph (4) (a), page 6-13.

2) Physical. Dimensions of attach flanges and holes should be inspected for a go or no-go condition.

5. Checkout.

Refer to paragraph (e), page 6-17.

(b) Nose Cone, Interstage and Pressure Regulator Assembly, Support Skirt, Support Bracket and Tankage Attach Bracket Assemblies.

See Figures 6-14 through 6-18, pages 6-37 through 6-40.

1. Physical Size and Weight.

	Nose Cone	Interstage & Press. Reg. Assy	Support Skirt	Tank Support Bracket	Tank Attach Bracket
Outside diameter, in.	64	64	64	48	64
Length, in.	72	48	50	55	4
Weight, lbs.	150	455	380	300	200

2. Environmental Protection.

Refer to paragraph c (2), page 6-12.

3. Support-Attach Points and Allowable Loading.

Support and attach points for all handling, transporting, storing, etc. should be through the attach flanges as required.

4. Inspection.

1) Visual. Refer to paragraph (4) (a), page 6-13.

2) Physical. Refer to paragraph (4) (b), page 6-18.

5. Checkout.

Refer to paragraph (e), page 6-17.

f. Ignition System.

(1) Igniter Motor Assembly.

Figure 6-19, page 6-41 illustrates a typical forward end of the igniter motor assembly and identifies its shape, attach areas, and internal propellant grain and insulation. (NOTE: For addditional discussion of ignition systems, see also page 6-5).

(a) General.

Propellant Classification, Environmental Protection and Visual Inspection are identical to those described for the Motor assembly. (See pages 6-9 and 6-11).

(b) Physical Size and Weight.

	Case with Propellant Loaded Cartridge		Case Closure	
	120-in.	156/260	120-in.	156/260
Outside Diameter, in.	20	30	20	30
Length, in.	35	50	5	8
Weight, lbs.	225	350	75	150

(c) Support-Attach Points and Allowable Loadings.

All handling, transporting, and storage should be accomplished through the igniter-closure attach flange and igniter motor case (cylindrical portion). Vertical handling and storage can be accomplished through the igniter-closure flange. Horizontal handling and storage will require both the igniter-closure attach flange and motor case support. Maximum allowable shock loads should not exceed 15 g's in any plane.

(d) Physical Inspection.

Dimensional tolerances of closure-igniter motor flange and S&A attach boss should be inspected for go or no-go condition.

(2) Safe and Arm (S&A) Assembly.

Figure 6-20, page 6-20 illustrates a typical S&A configuration and identifies its shape, attach areas and components.

(a) Physical Size and Weight.

	120/156/260
Outside diameter, in.	6
Length, in.	4
Weight, lbs.	5

(b) Explosive Classification.

Based on the ignition pellet composition (Boron-Potassium Nitrate), the S&A assembly would be classified as class "C" explosive, as defined in Interstate Commerce Commission Regulations, Tarriff No. 13. Other propellant combinations would also be classified according to this tarriff regulation.

(c) Environmental Protection.

Special temperature and humidity control will not be required for this particular assembly because it is considered to be a hermetically sealed unit. (Ambient temperatures experienced during normal shipment and storage will not effect the composition). Adequate protection against corrosion, deterioration, and physical damage during handling and shipping should be in accordance with Federal Standard No. 102, level "C". The maximum environmental RF

energy density exposure for this assembly (based on the electrical squib limitation) is 1 watt at 3000 mc. Other types of S&A assemblies would have to be evaluated accordingly.

(d) Support-Attach Points and Allowable Loading.

There are no special support-attach requirements for this assembly. Maximum allowable shock loads should not exceed 10 g's in any plane.

(e) Inspection.

Refer to paragraph (4), page 6-13.

Dimensional tolerances of the S&A igniter motor attach flange shall be inspected for a go-no-go condition.

(f) Checkout.

The electro-mechanical checkout requirements for this particular Safe and Arm assembly are as follows:

PARAMETER	RANGE
Safe Command Circuit	25-40-v-dc
Arm Command Circuit	25-40-v-dc
Safe Position Indicator	Full Safe
Arm Position Indicator	Full Arm
Simulator Resistor	1-2 ohms at 4-5 amps
Squib	1-2 ohms at 4-5 amps
Detonator (260 only)	1-2 ohms at 4-5 amps

Other S&A assemblies would be considered accordingly.

g. Thrust Termination and Destruct System.

(1) Thrust Termination (T. T.) Port Covers and Stacks. (120 and 156-Inch Motors Only).

Figure 6-21, page 6-42 illustrates the port cover and stack configuration for the 120-inch and 156-inch motors and identifies its shape and attach areas. At the present time no data is available on thrust termination of motors larger than 156 inches in diameter. However, it appears that any provisions would be of a similar design.

(a) Physical Size and Weight.

	PORT COVER		STACK	
	120-inch	156-inch	120-inch	156-inch
Outside diameter, in.	35	45	40	50
Length, in.	8	8	25	60
Weight (each) lbs.	300	425	150	250

(b) Environmental Protection and Visual Inspection.

Refer to paragraph c (2), page 6-12 and (4) (a), page 6-13.

(c) Physical Inspection.

Dimensional accuracy of mating attach flanges and holes shall be inspected for go-no-go condition.

(2) Safe and Arm (S&A) Assembly (Thrust Termination & Destruct System.)

Refer to paragraph f (2), page 6-20 for a discussion of Safe and Arm assemblies. Size and type of unit will naturally vary with application.

(3) Shaped Charges.

Figure 6-22, page 6-42 shows the shaped charges for the Thrust Termination system (120 and 156-inch only) while Figure 6-23, page 6-42 shows them for the Destruct System (all three sizes).

(a) Physical Sizes and Weights (Shaped Charge Only).

	Thrust Termination System		Destruct System		
	120-inch	156-inch	120-inch	156-inch	260-inch
Outside Diameter, in.	30	40			
Cross Section, in.	2x3	3x3	2x3	2x3	2x3
Length, in.	---	---	110	110	138
Weight, lbs.	5	8	5	5	7

(b) Explosive Classification.

Explosive classification of the shaped charge and transfer harness will be class "A", as described in Interstate Commerce Commission Regulations, Tariff No. 13. Other types would be classified according to their composition.

(c) Environmental Protection.

Temperature of the referenced shape charge and transfer harness should be maintained within 0 to 165°F.

Adequate protection against corrosion, deterioration, and physical damage during handling and shipping will be in accordance with Federal Standard No. 102, level "C".

(d) Visual Inspection.

Refer to paragraph (4), page 6-13.

h. Ground Instruction Requirements.

To provide for a satisfactory evaluation of motor performance throughout development and flight test, there will be requirements to monitor, record and evaluate certain motor parameters. Figure 6-24, page 6-43 indicates those parameters applicable to the assembled rocket motor and the component handling and storage function.

FOR DISCUSSION REFER TO PAGE 6-4

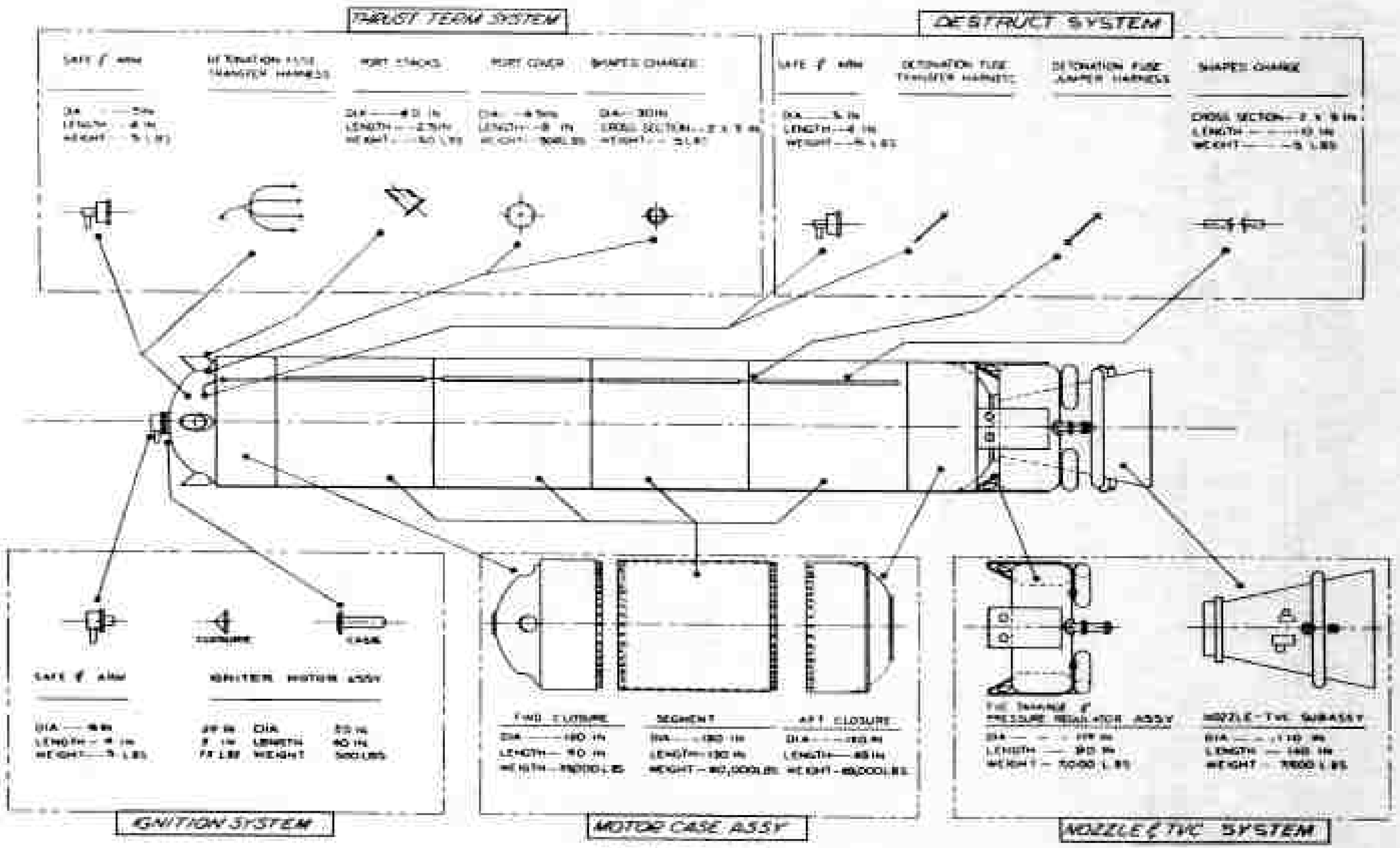


FIGURE 6-1
MAJOR COMPONENTS
120 INCH DIAMETER SEGMENTED SOLID PROPELLANT ROCKET MOTOR

FOR DISCUSSION REFER TO PAGE 6-4

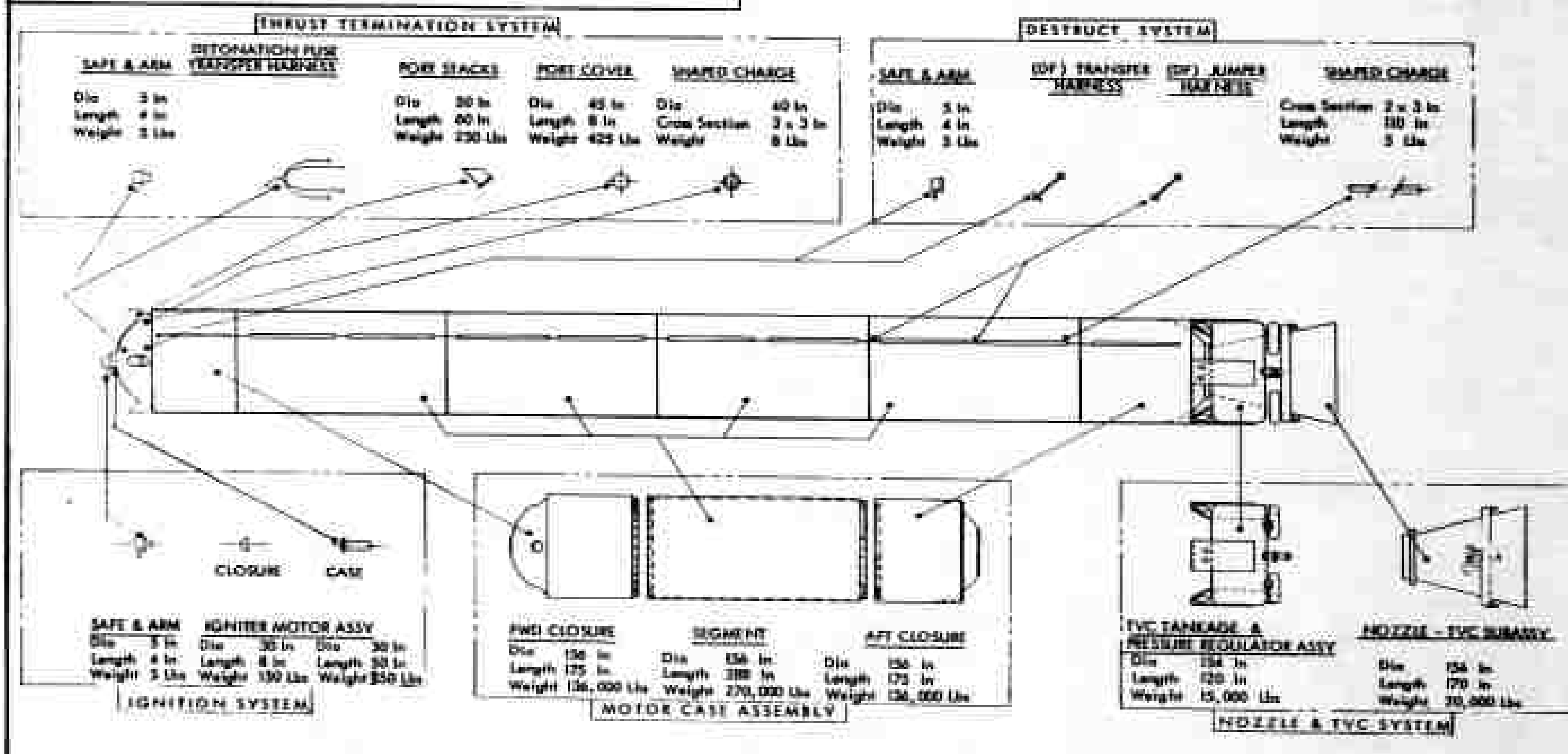


FIGURE 6-2
MAJOR COMPONENTS, 156-INCH DIAMETER SEGMENTED, SOLID PROPELLANT ROCKET MOTOR

FOR DISCUSSION REFER TO PAGE 6-5

United Technology Center

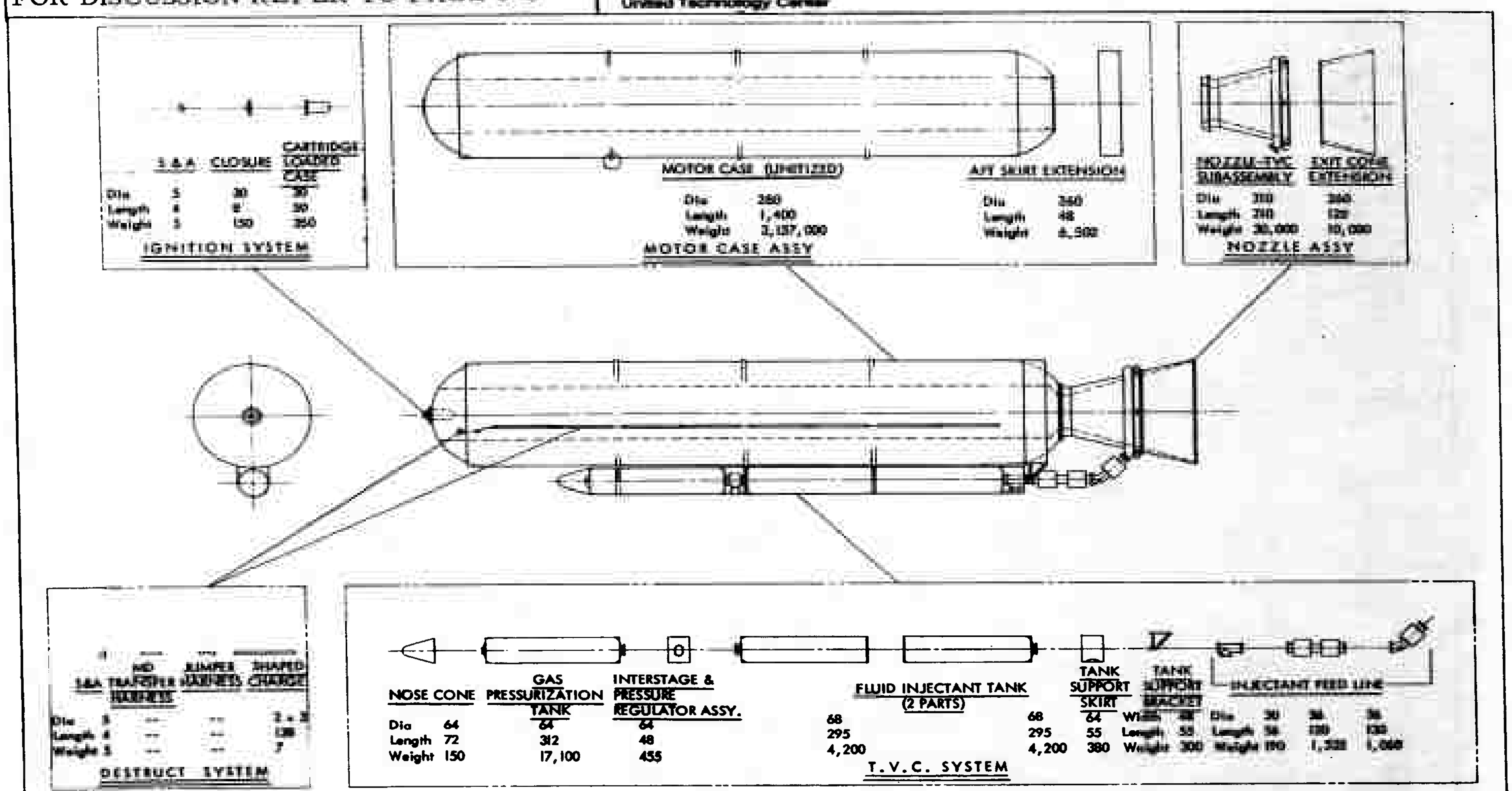


FIGURE 6-3
MAJOR COMPONENTS, 260-INCH DIAMETER, UNITIZED, SOLID PROPELLANT ROCKET MOTOR

FOR DISCUSSION
REFER TO PAGE 6-6

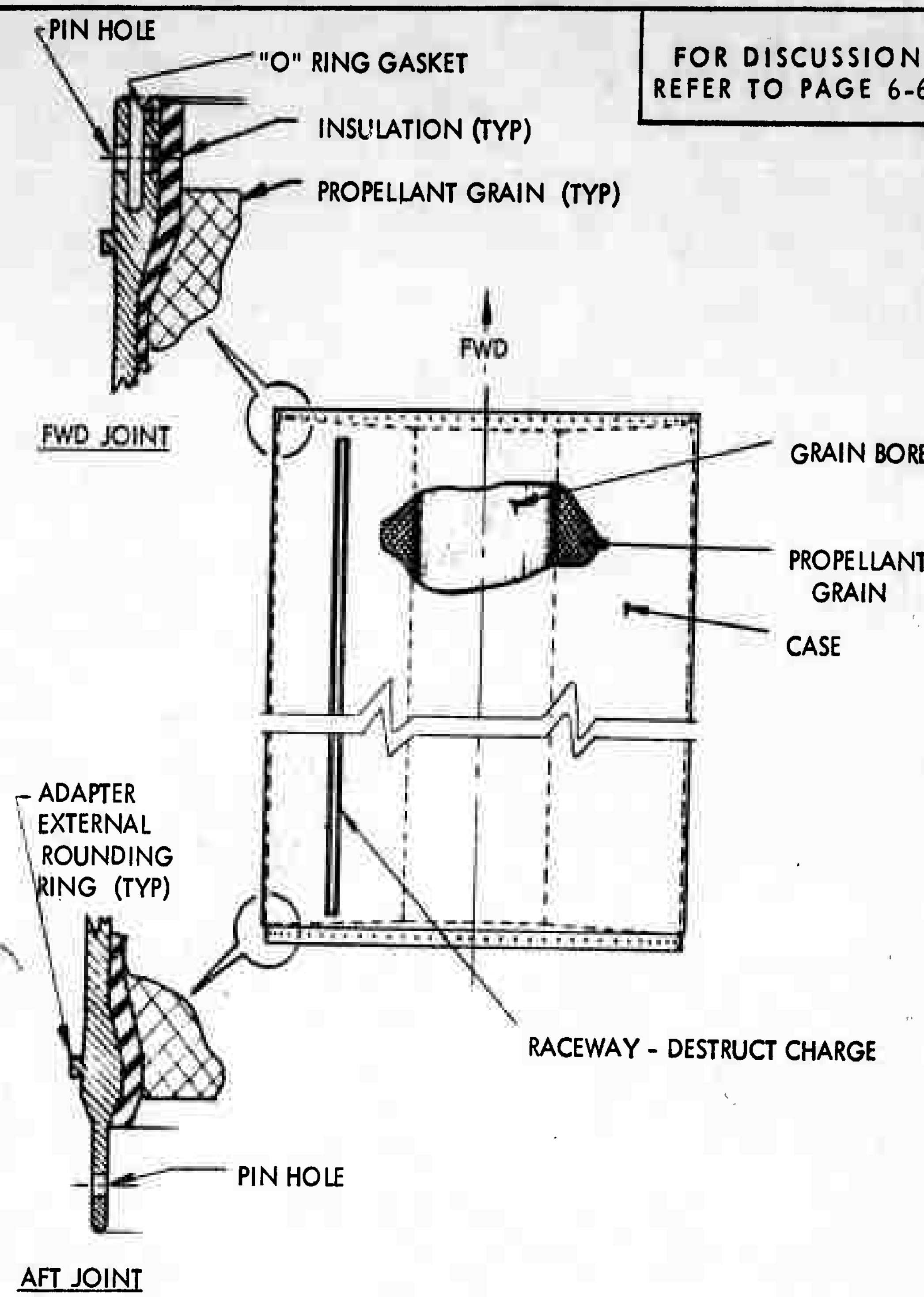


FIGURE 6-4
SEGMENT (TYPICAL)

FOR DISCUSSION REFER TO PAGE 6-6

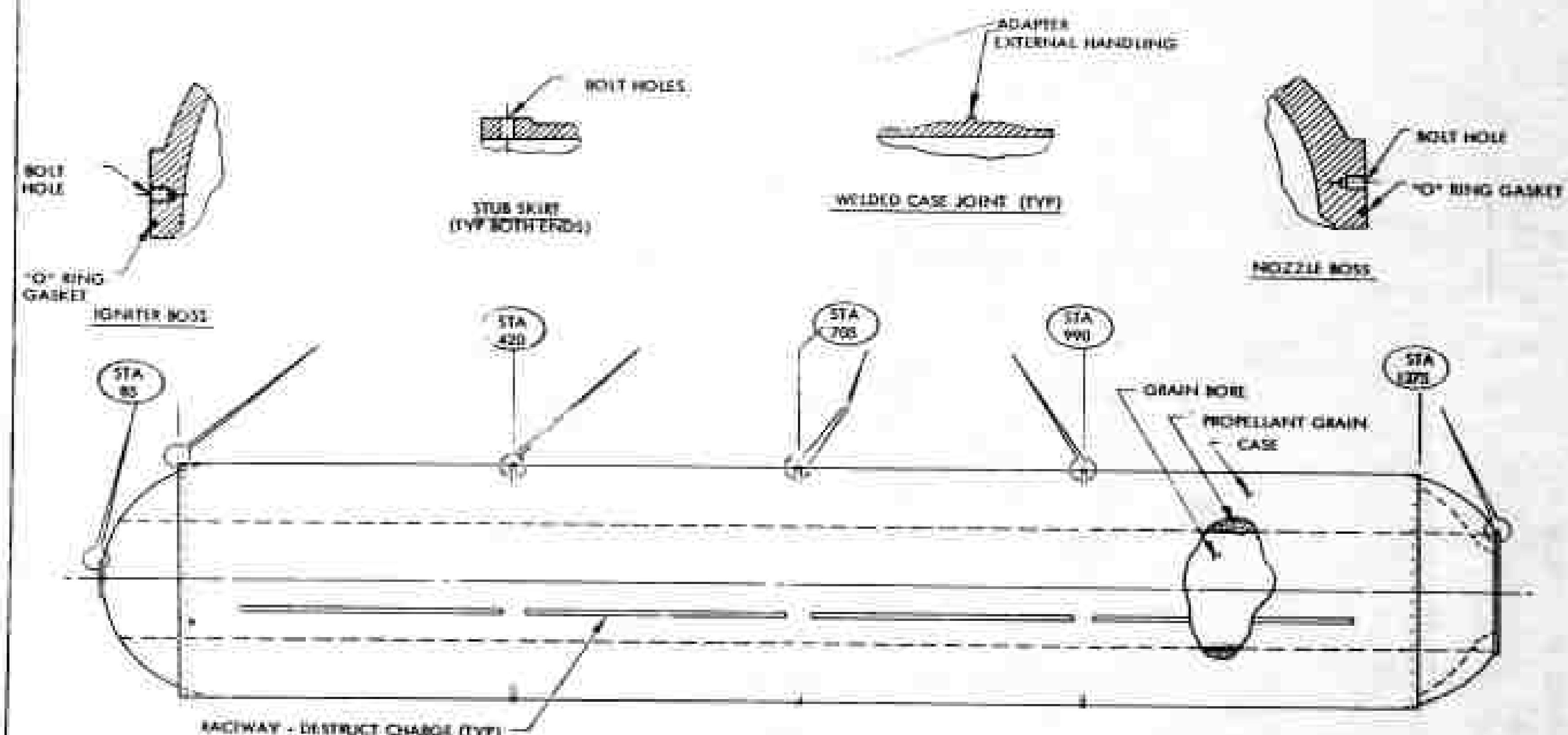


FIGURE 6-5
260-INCH UNITIZED MOTOR CASE

FOR DISCUSSION REFER TO PAGE 6-9

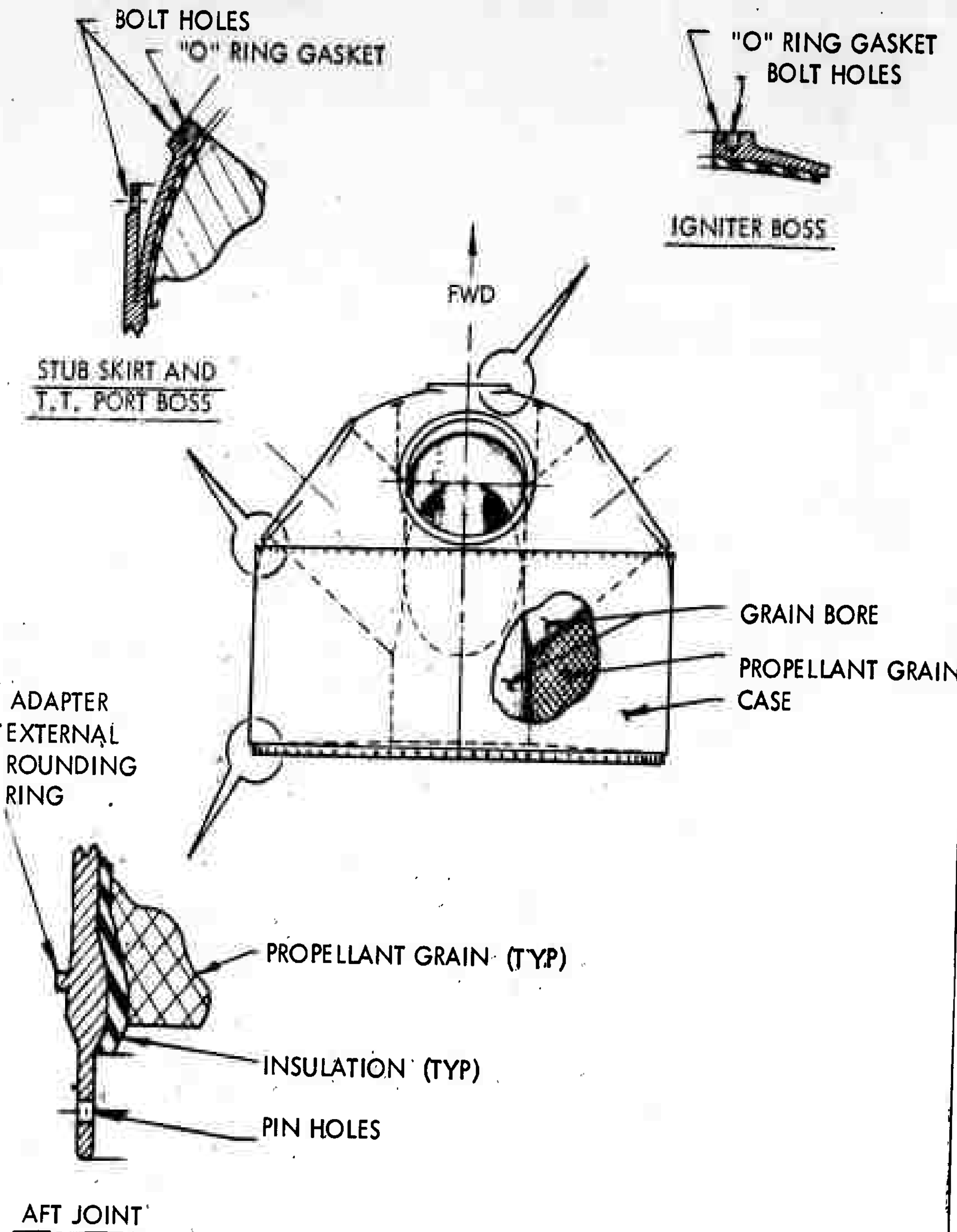


FIGURE 6-6
FORWARD CLOSURE

FOR DISCUSSION REFER TO PAGE 6-9

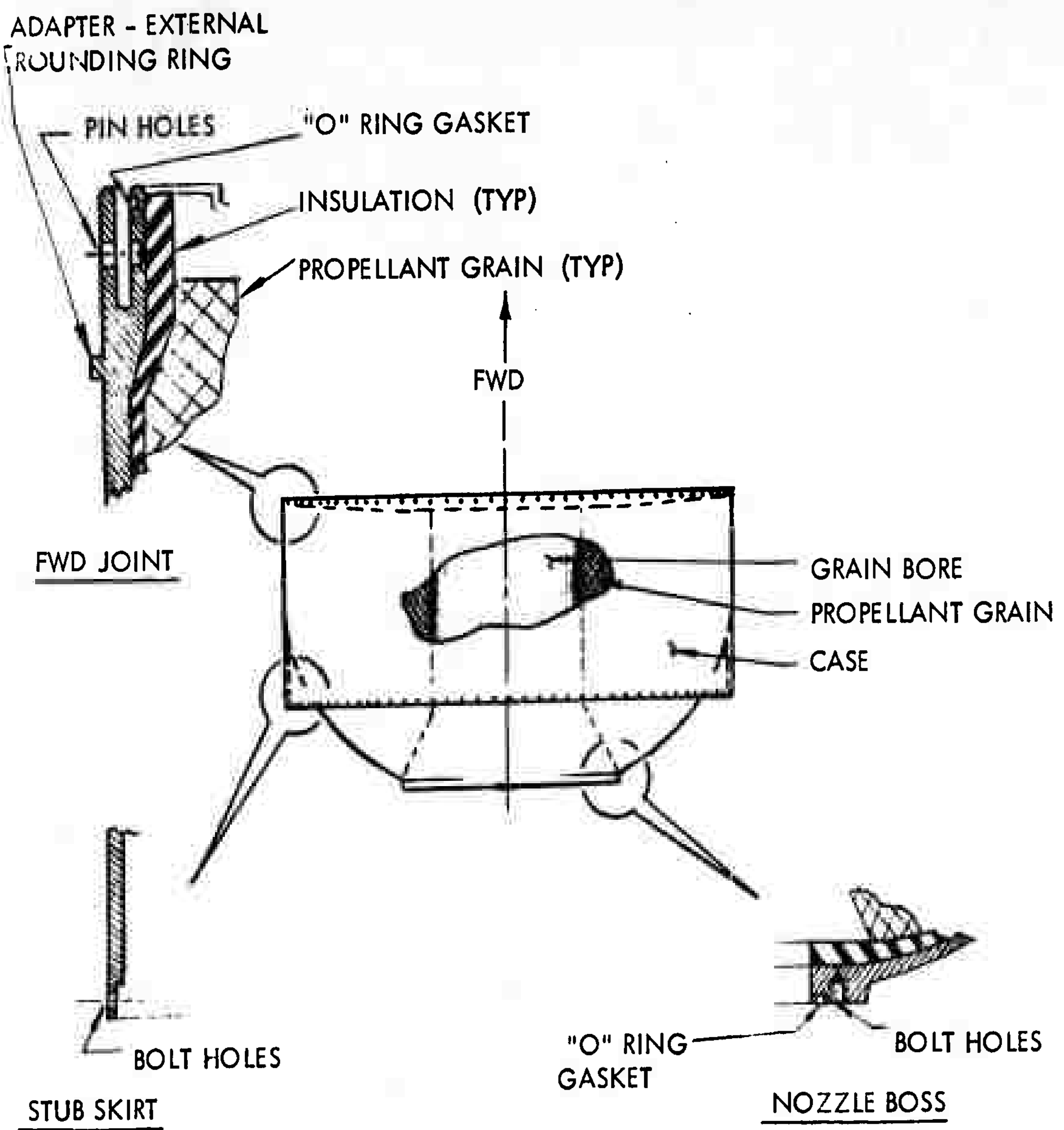


FIGURE 6-7
AFT CLOSURE

FOR DISCUSSION REFER TO PAGE 6-10

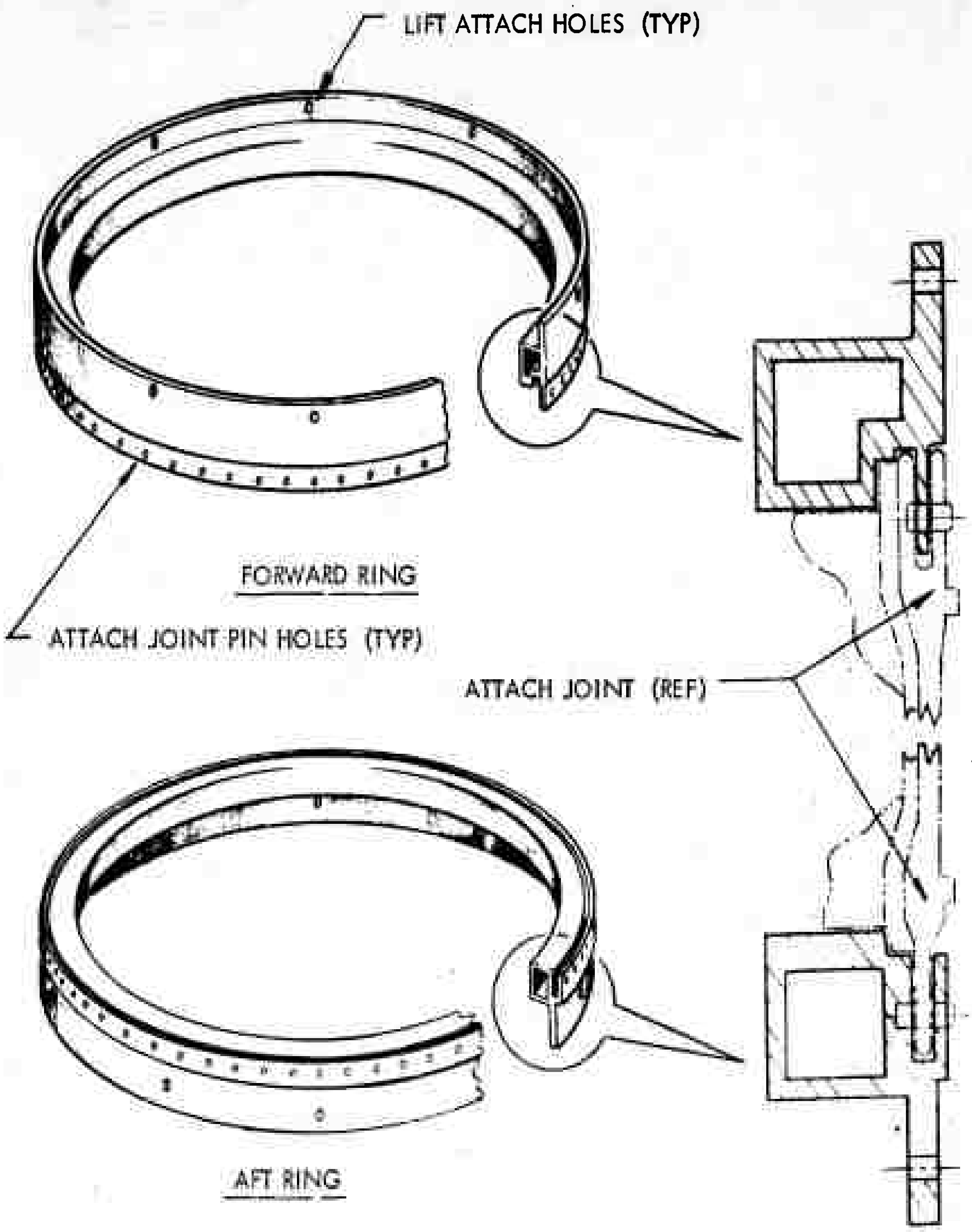


FIGURE 6-8
INTERNAL ROUNDING - HANDLING RINGS

FOR DISCUSSION REFER TO PAGE 6-12

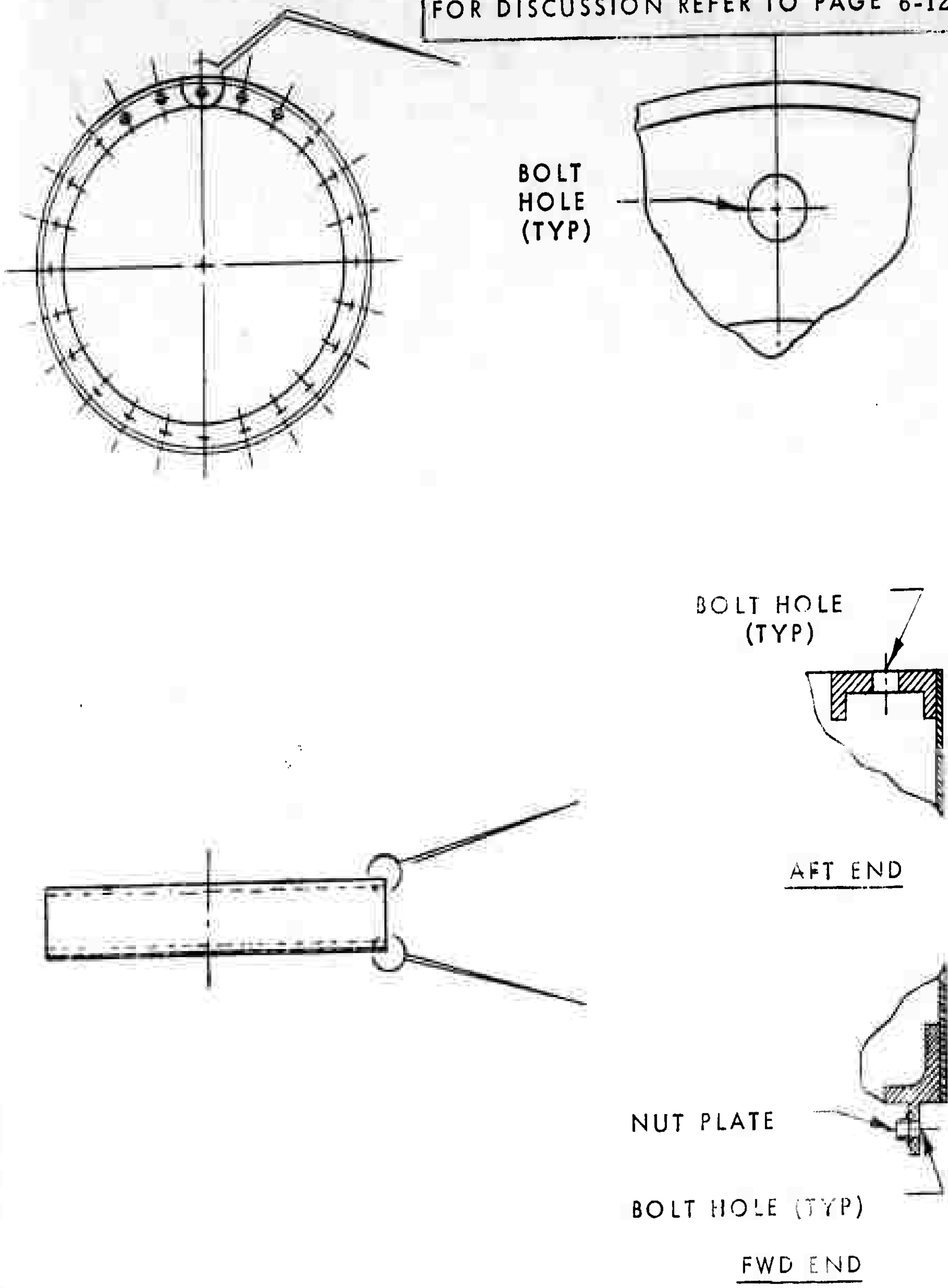


FIGURE 6-9
AFT SKIRT EXTENSION

FOR DISCUSSION REFER TO PAGE 6-13

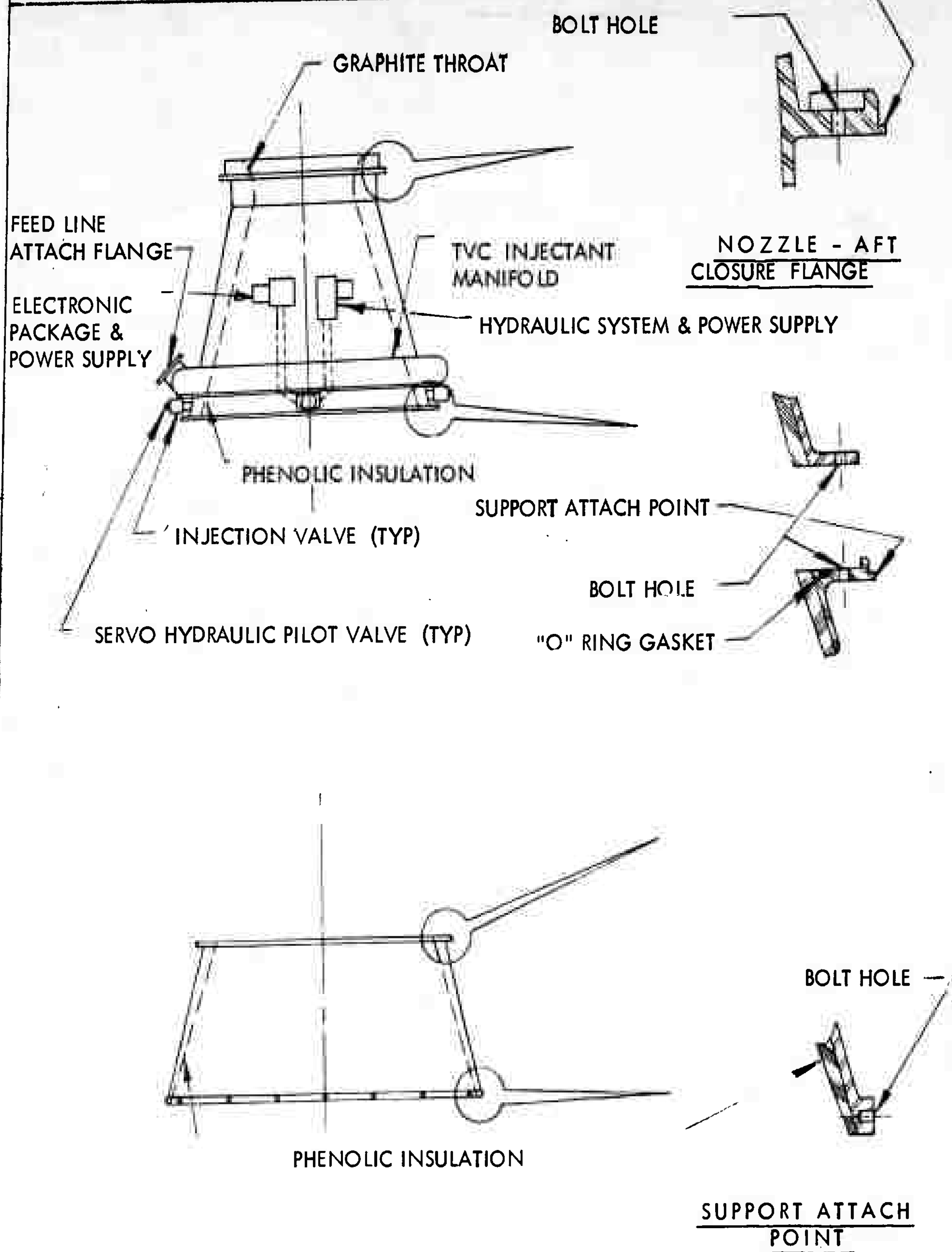


FIGURE 6-10

NOZZLE - TVC SUBASSEMBLY AND EXIT CONE EXTENSION

FOR DISCUSSION REFER TO PAGE 6-14

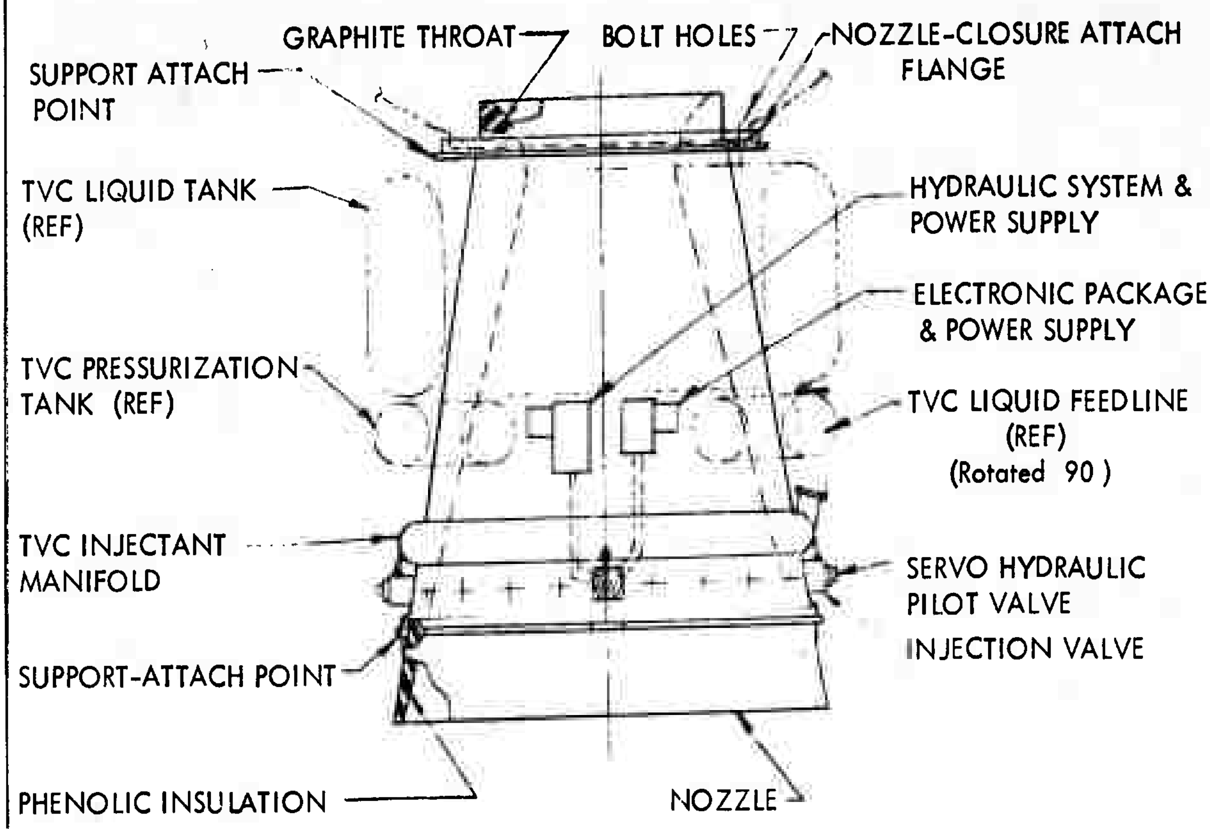


FIGURE 6-11
NOZZLE - TVC SUBASSEMBLY

FOR DISCUSSION REFER TO PAGE 6-16

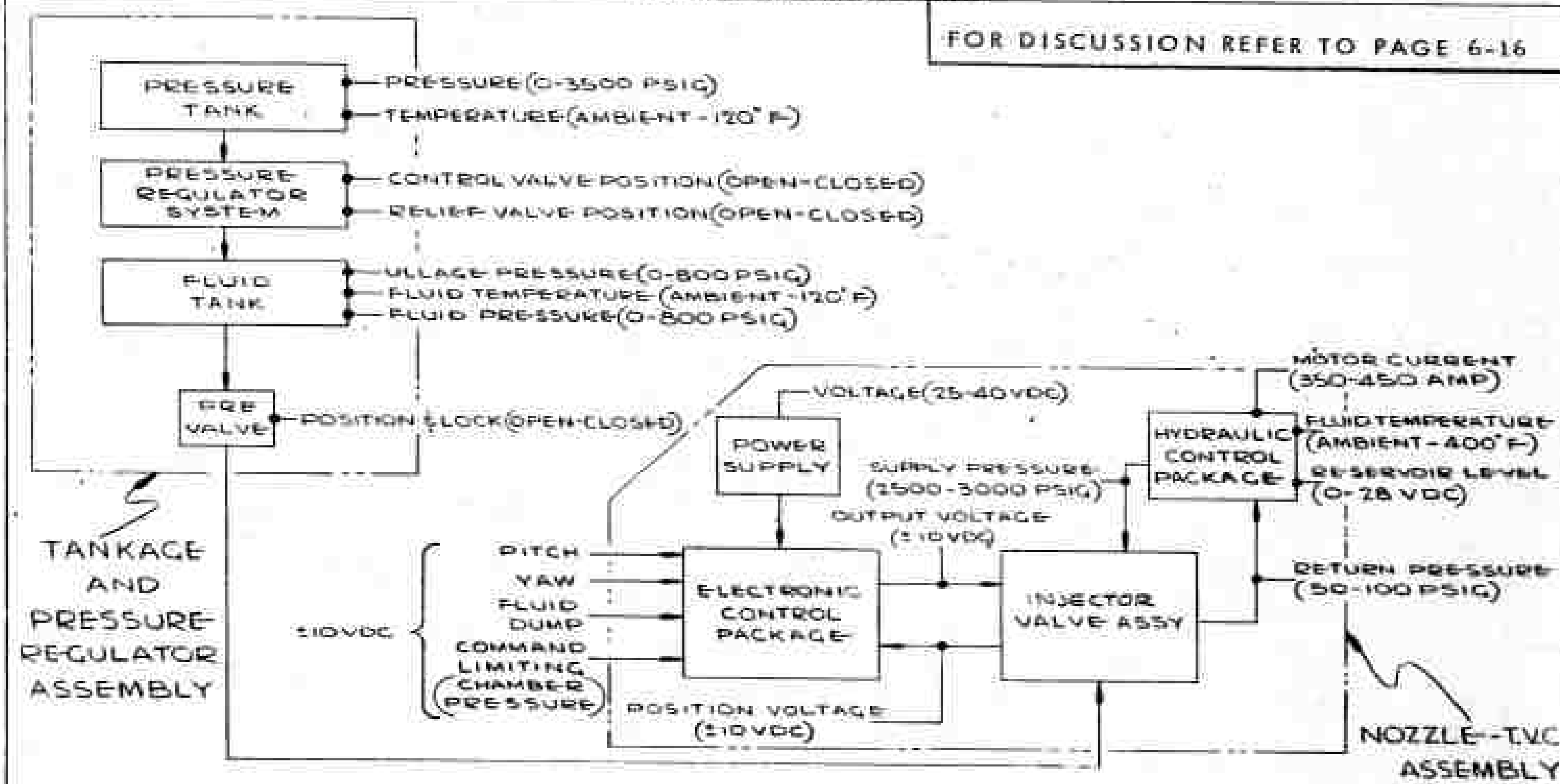


FIGURE 6-12

T.V.C. SYSTEM FLOW AND CHECKOUT REQUIREMENTS

FOR DISCUSSION REFER TO PAGE 6-16

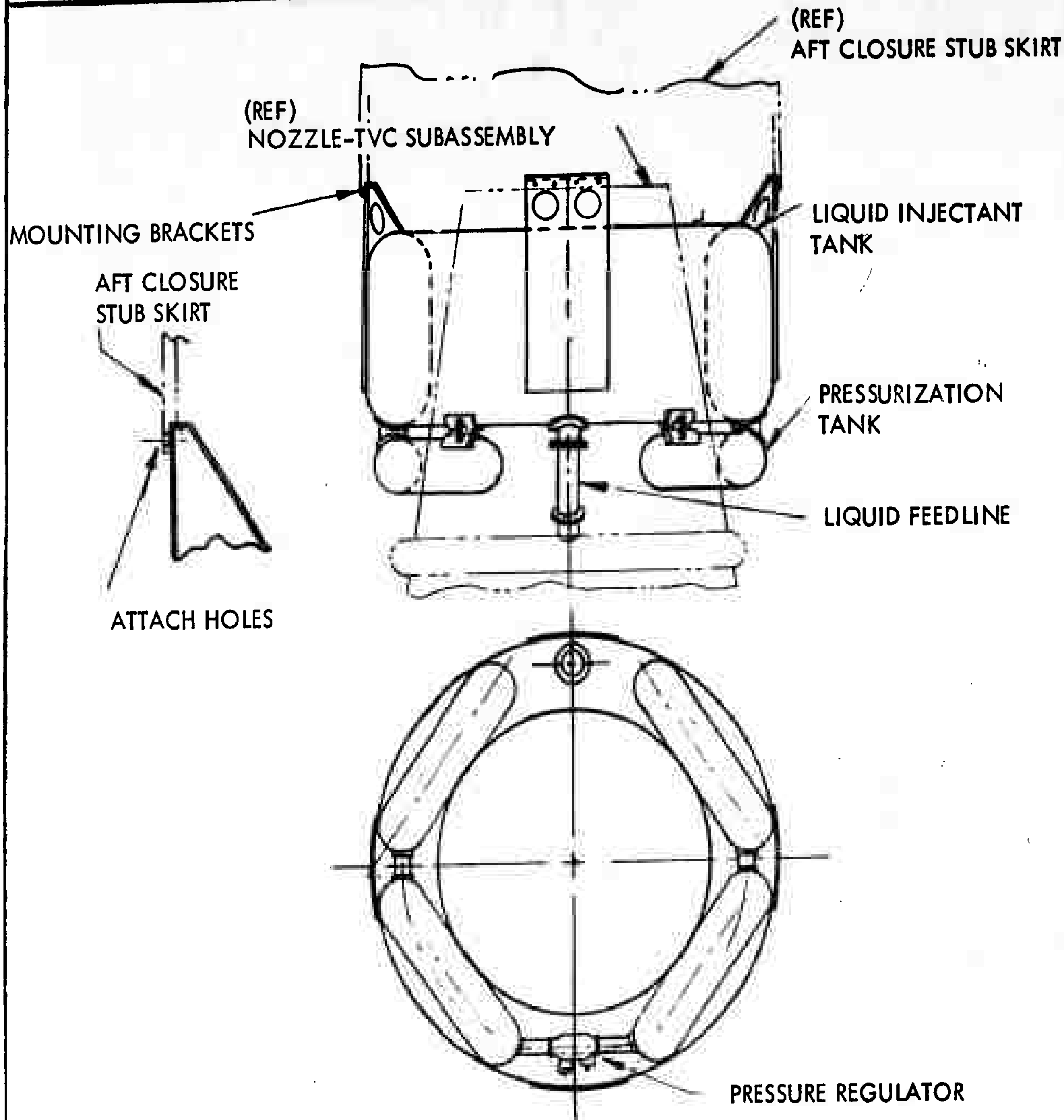


FIGURE 6-13
T.V.C. TANKAGE & PRESSURE REGULATOR ASSEMBLY

FOR DISCUSSION REFER TO PAGE 6-17

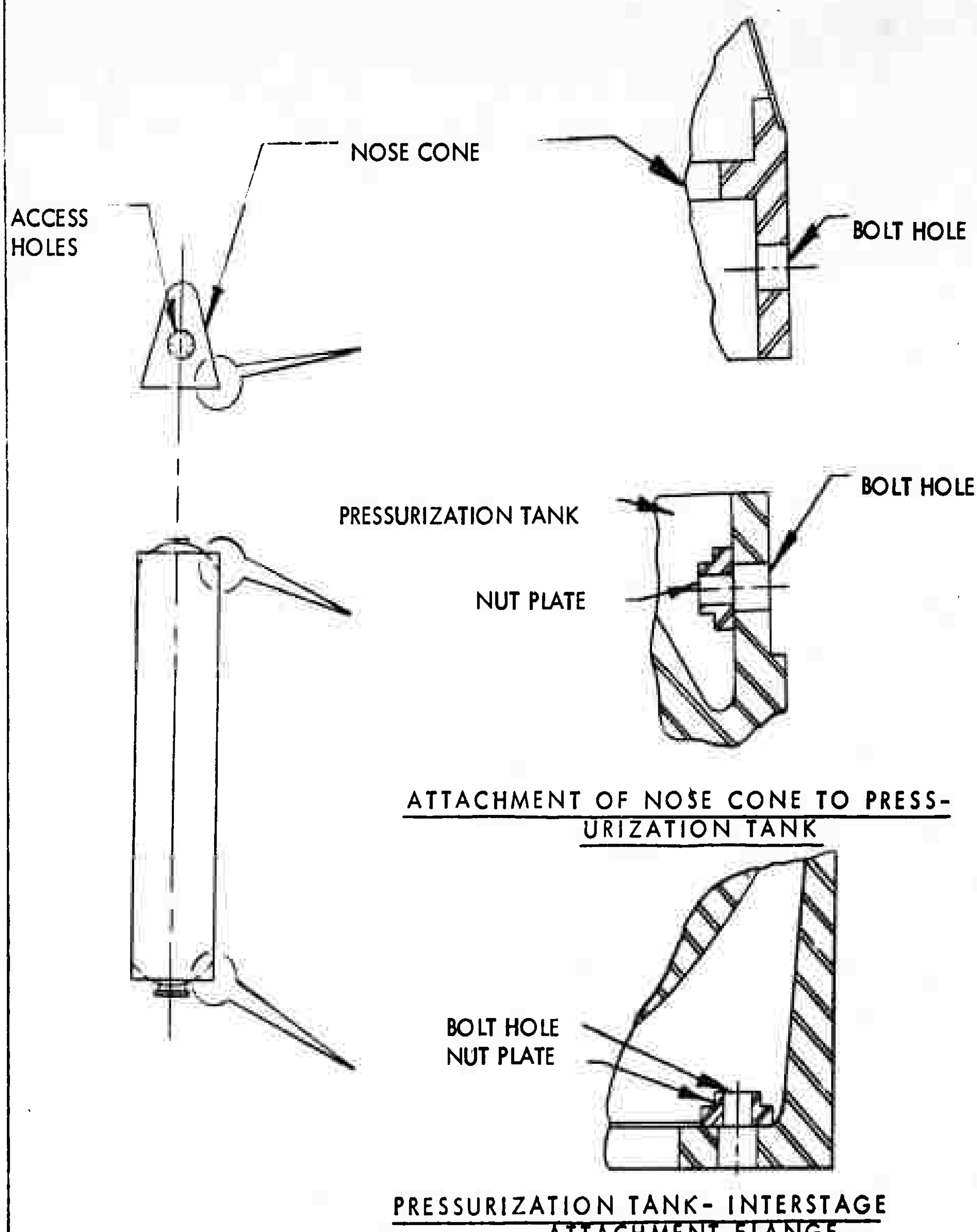


FIGURE 6-14
NOSE CONE & PRESSURIZATION TANK

FOR DISCUSSION REFER TO PAGE 6-17

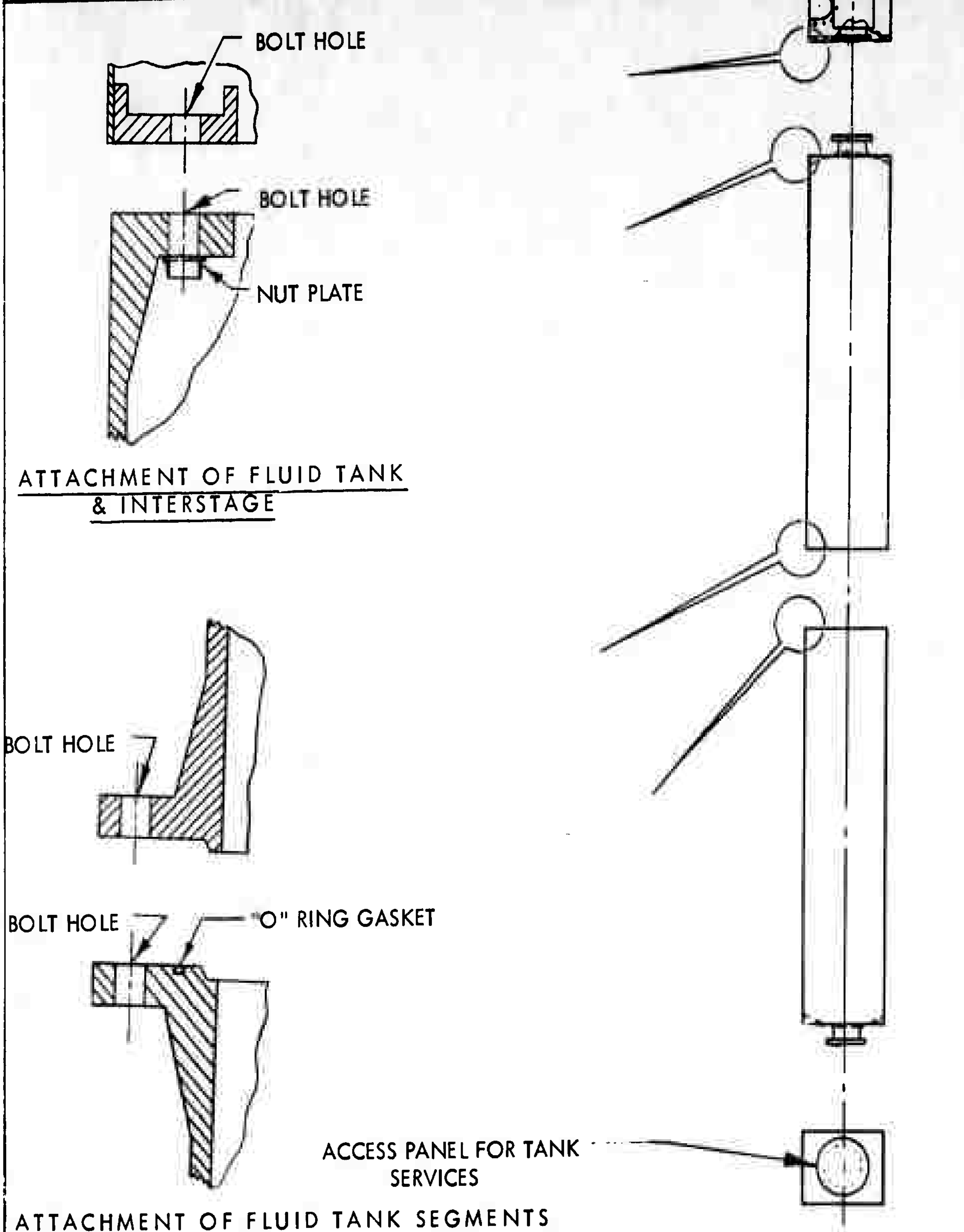


FIGURE 6-15
INTERSTAGE & PRESSURE REGULATOR ASSY/INJECTANT TANK & TANK SUPPORT SKIRT

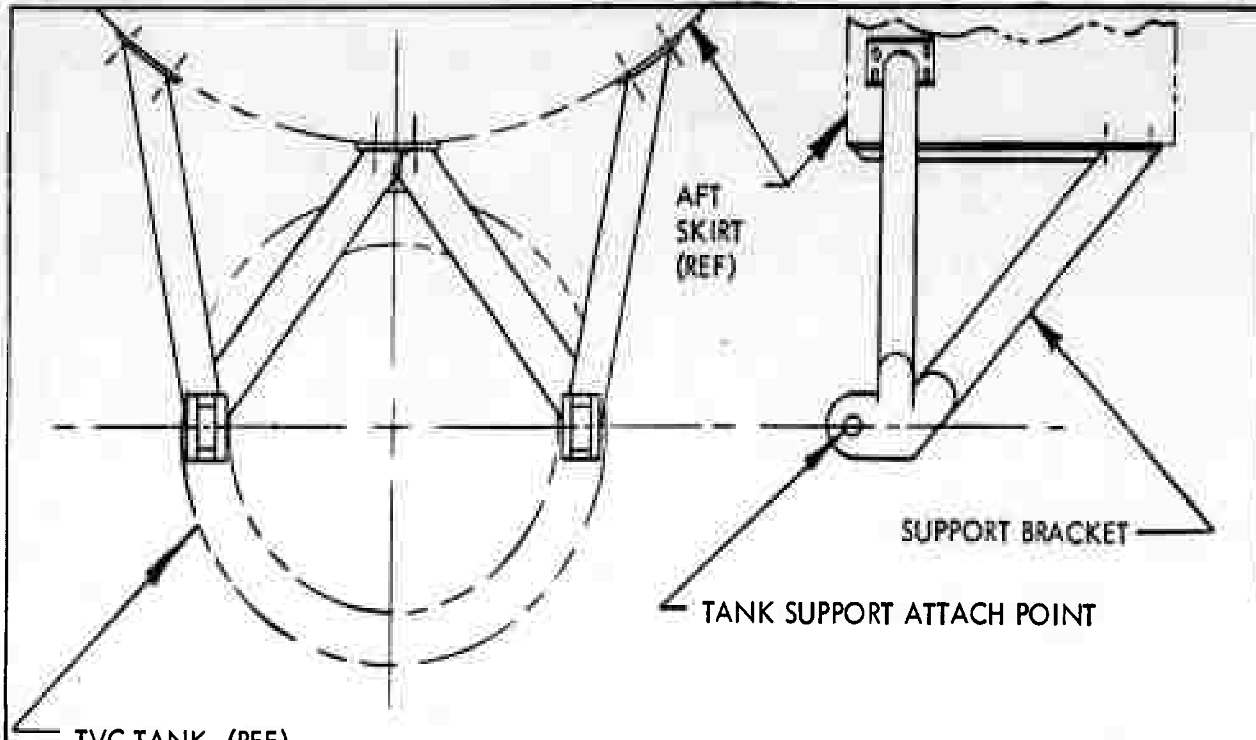


FIGURE 6-17
TANK SUPPORT BRACKET

FOR DISCUSSION
REFER TO PAGE 6-18

FOR DISCUSSION
REFER TO PAGE 6-17

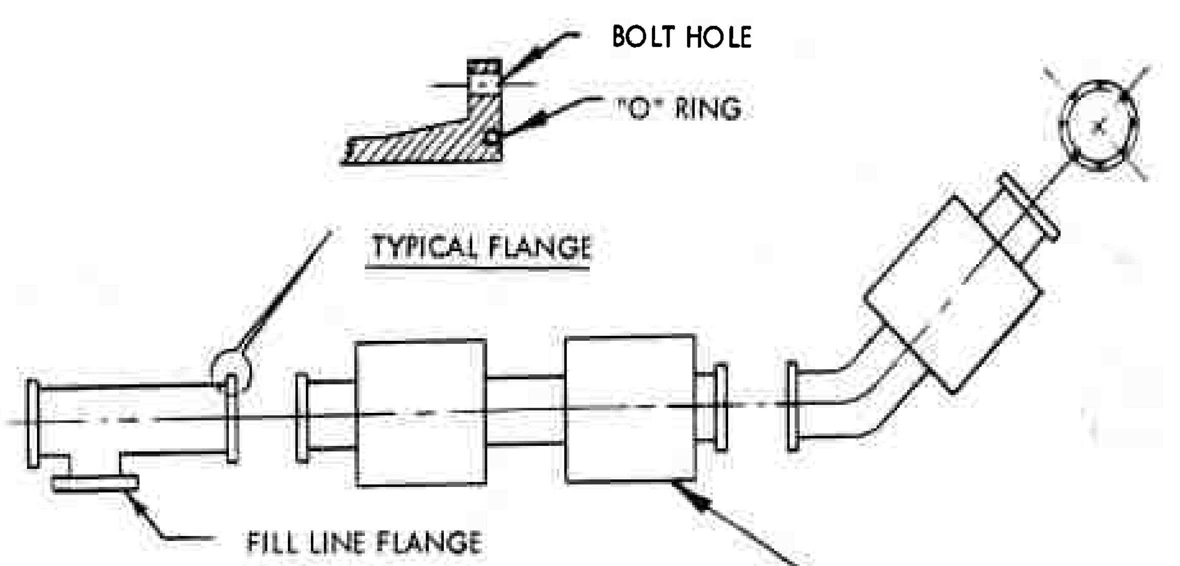


FIGURE 6-16
INJECTANT LINE ASSEMBLY

FOR DISCUSSION REFER TO PAGE 6-18

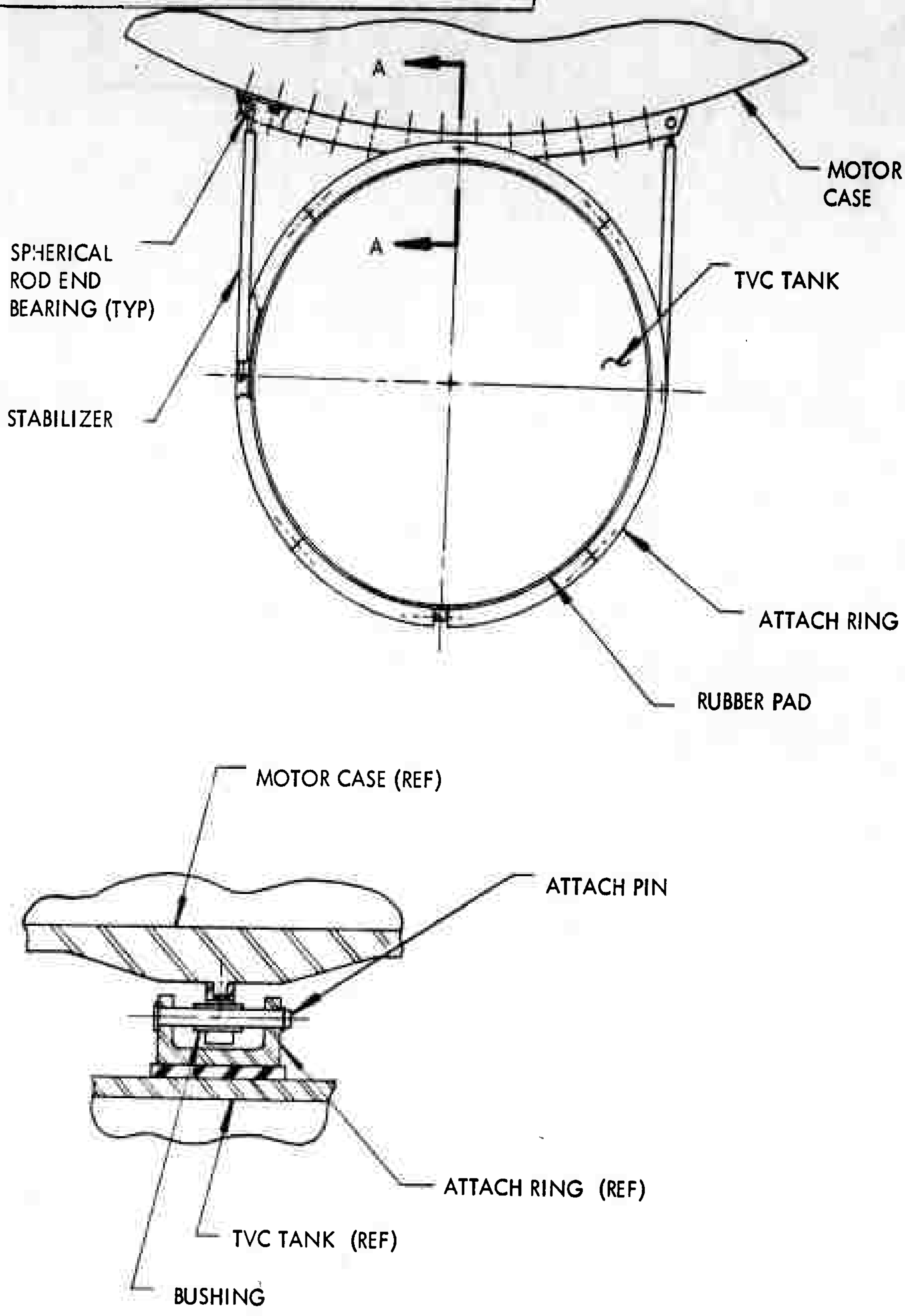


FIGURE 6-18
TVC TANKAGE ATTACH BRACKET ASSEMBLY

FOR DISCUSSION REFER TO PAGE 6-19

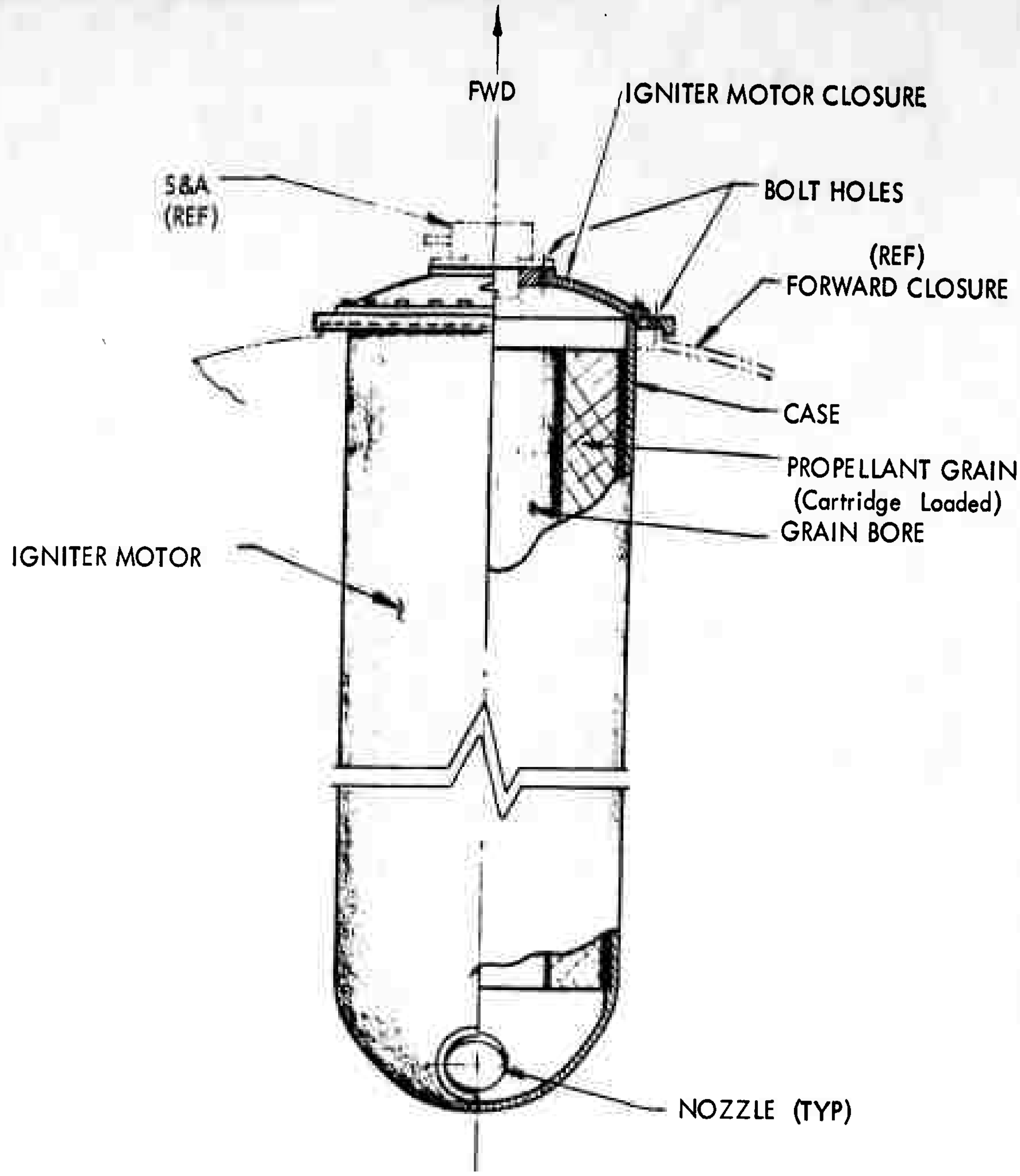


FIGURE 6-19
IGNITER MOTOR ASSEMBLY

FOR DISCUSSION
REFER TO PAGE 6-20

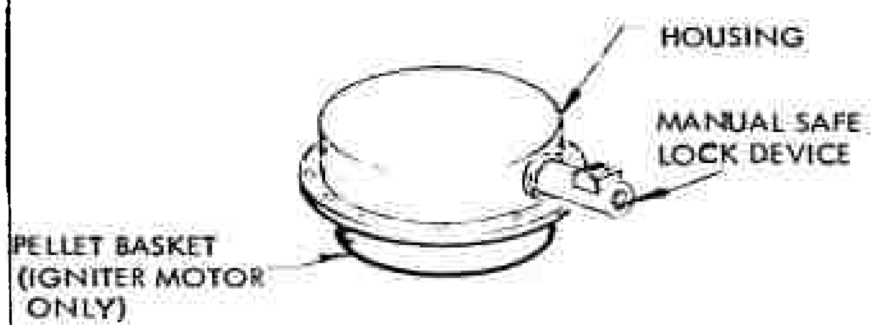


FIGURE 6-20
SAFE AND ARM ASSY.

FOR DISCUSSION
REFER TO PAGE 6-21

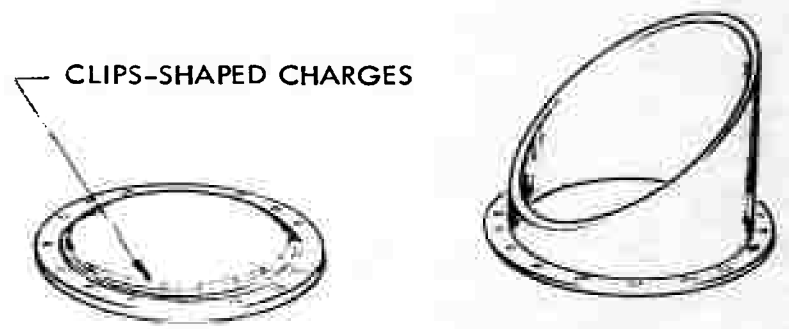


FIGURE 6-21
T.T. PORT COVER T.T. PORT STACK

FOR DISCUSSION
REFER TO PAGE 6-22

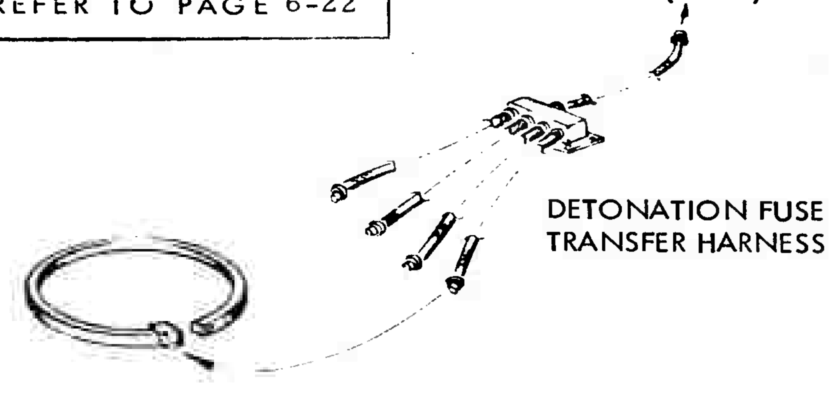


FIGURE 6-22
T.T. SHAPED CHARGE & (DF)
TRANSFER HARNESS

FOR DISCUSSION
REFER TO PAGE 6-22

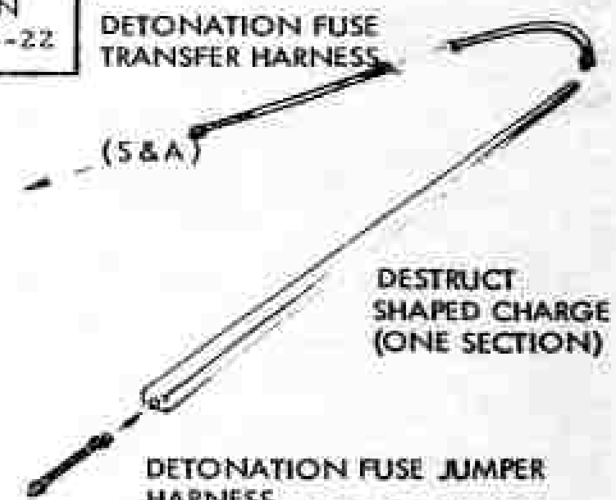


FIGURE 6-23
(DF) TRANSFER & JUMPER HARNESSES

FOR DISCUSSION REFER TO PAGE 6-23

FIGURE 6-24
GROUND SYSTEM REQUIREMENTS

PARAMETER	RANGE	FREQUENCY (CPS)	ACCURACY (%)
MOTOR HEAD END PRESSURE	0-1, 500 PSIA	100	2
MOTOR CASE STRAIN	0-5,000 MICRO-INCHES PER INCH	2000	10
NOZZLE STRAIN	0-5,000 MICRO-INCHES PER INCH	2000	10
MOTOR CASE TEMPERATURE	0-500°F	10	5
NOZZLE CASE TEMPERATURE	0-500°F	10	5
MOTOR ACCELERATION (3 PLANES)	0-10 G's	1000	3
MOTOR THRUST (LONGITUDINAL) (STATIC TEST ONLY)			
120 - INCH DIAMETER MOTOR			
ONE SEGMENT	0-.30 x 10^6 LBS	100	2
TWO SEGMENTS	0-.45 x 10^6 LBS	100	2
THREE SEGMENTS	0-.60 x 10^6 LBS	100	2
FOUR SEGMENTS	0-.75 x 10^6 LBS	100	2
FIVE SEGMENTS	0-.90 x 10^6 LBS	100	2
SIX SEGMENTS	0-1.1 x 10^6 LBS	100	2
156 - INCH DIAMETER MOTOR			
ONE SEGMENT	0-1.0 x 10^6 LBS	100	2
TWO SEGMENTS	0-1.5 x 10^6 LBS	100	2
THREE SEGMENTS	0-2.0 x 10^6 LBS	100	2
FOUR SEGMENTS	0-2.5 x 10^6 LBS	100	2
FIVE SEGMENTS	0-3.0 x 10^6 LBS	100	2
260 - INCH DIAMETER MOTOR	0-9.0 x 10^6 LBS	100	2
NOZZLE SIDE THRUST (2 DIRECTIONS)	8.5 % OF LONGIT-UDINAL THRUST	100	2
IGNITER CASE PRESSURE	0-3,000 PSIA	1000	10
THRUST TERMINATION INPUT	28-32 V-DC	10	5
THRUST TERMINATION BREAKWIRE	28-32 V-DC	—	10
MOTOR DESTRUCT INPUT	28-32 V-DC	10	5
VIBRATION	0-100 G's	2000	10
ACOUSTIC	0-200 DB's	2000	3

PARAMETER	RANGE	FREQUENCY (CPS)	ACCURACY (%)
TVC FLUID TANK PRESSURE	0-800 PSIA	100	2
PRESSURIZATION TANK PRESSURE	0-3,500 PSIA	100	2
INJECTION PRESSURE	0-800 PSIG	1000	2
HYDRAULIC SUPPLY PRESSURE	2,500-3,500 PSIG	100	5
HYDRAULIC RETURN PRESSURE	50-100 PSIG	100	5
FLUID TEMPERATURE	0-120°F	10	5
HYDRAULIC FLUID TEMPERATURE	0-400°F	10	5
HYDRAULIC RESERVOIR LEVEL	0-28 V-DC	10	2
HYDRAULIC PUMP MOTOR CURRENT	300-450 AMPS	10	2
COMPONENT TEMPERATURE	0-400°F	10	5
INJECTOR VALVE POSITION	± 10 V-DC	100	2
PRESSURE REGULATOR RELIEF VALVE	OPEN - CLOSED	100	-
PRESSURE REGULATOR CONTROL VALVE	OPEN - CLOSED	100	-
COMMAND SIGNALS			
PITCH	±10 V-DC	100	2
YAW	±10 V-DC	100	2
TVC FLUID PUMP	±10 V-DC	100	2
COMMAND LIMITING (CHAMBER PRESSURE)	±10 V-DC	100	2
BATTERY AND BUS. VOLTAGE	25-40 V-DC	10	2
PHOTO COVERAGE AS REQUIRED			
COMPONENT HANDLING & STORAGE			
PROPELLANT TEMPERATURE	-35 TO -160°F	LESS THAN 1	2
STRUCTURAL TEMPERATURE	-35 TO -160°F	LESS THAN 1	2
RELATIVE HUMIDITY	0-100 PERCENT	—	5
ACCELERATION	0-100 G's	10	3

2. TYPICAL AREAS OF ACTIVITY AND RELATED FUNCTIONAL REQUIREMENTS – 120 AND 156-INCH DIAMETER SEGMENTED SOLID PROPELLANT ROCKET MOTORS

a. General.

This section describes typical functional areas, series of events, and functional requirements for the major segmented motor components at the motor manufacturing site, static test site, and launch site. For each area, preliminary AGE is suggested. (The functional flow charts and diagrams which are referenced in the following paragraphs do not show the flow and accountability of rejected components).

b. Motor Manufacturing Site.

Figure 6-25, page 6-70 is a chart showing the flow of major motor components through the various functional areas (processing stations). These functional areas are defined as follows: receipt of hardware from motor manufacturing vendor, processing, subassembly, preparation for shipping and shipping to either the motor static test or the launch site. Those processing functions (hardware preparation, propellant casting and curing, and casting equipment stripping) which need special tooling, will not be discussed in this report because this type of requirement is considered process tooling rather than Aerospace Ground Equipment. Figures 6-26 through 6-30, pages 6-71 through 6-75 describe the handling procedures which are performed on each major motor component as it is routed through the various processing stations in the motor manufacturing site.

SEGMENTED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
1. INERT HARDWARE RECEIVING, INSPECTION AND DISTRIBUTION. All incoming inert materials are received and inspected in this area. Upon acceptance, they are properly packaged and forwarded to their respective areas for storage or immediate use.	Necessary cranes, handling fixtures and dollies to off-load and process the various items of inert hardware (i. e., segment and closure cases, nozzles, TVC system components, etc.)

SEGMENTED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
2. INERT HARDWARE PREPARATION. This facility provides for the general cleaning of motor hardware items, lining and insultation operations as well as the cleaning and assembly of casting equipment. The cleaning operation includes vapor degreasing, grit blasting, etc. The lining and insulation operations include preparation, application to the motor and igniter case hardware and curing of liner and insulation.	Same equipment as for paragraph 1 above. For off-loading techniques see Figures 5-2 and 5-3, pages 5-14 and 5-15.
3. PROPELLANT CASTING AND CURING. This facility provides for the casting of propellant into prepared motor and igniter case hardware. Upon completion of the propellant casting operation, the motor and igniter propellant grains are allowed to cure under controlled conditions.	Equipment required in areas 3 and 4 will depend on facility lay-out for propellant and empty case handling Mandrel placement and removal equipment, environment control for propellant curing, etc. Lifting and handling equipment required for area 5 would satisfy these requirements.
4. CASTING EQUIPMENT STRIPPING AND COMPONENT INSPECTION. After curing of the propellant, casting equipment must be removed and the components inspected, AGE will be required following the removal of the process tooling.	
5. POST CASTING INSPECTION. NOTE: After the removal of all propellant casting equipment, it will be assumed that the segment consists of a propellant-loaded case with attach joint internal rounding-handling rings installed.	
a. 120-Inch Diameter Segment.	
(1) Install external round ring to each end of the segment.	Roller Dolly - 50 ton cap. Figure 7-3, page 7-7.
(2) Remove the upper internal rounding handling ring and inspect the segment.	Two 5-ton Mobile Hoists.
(3) Replace the upper internal rounding-handling ring and remove the external rounding ring.	Hoist-Slings.
(4) Lift the segment and remove the lower internal rounding-handling ring.	50-ton Overhead crane. (See Section 8).
(5) Place the segment on an inspection fixture which will accept the lower attach joint and still allow the required inspection.	Radiographic Linac (see Section 10). Inspection Platform (Figure 5-9, page 5-21. Ultrasonic Inspection system. Equipment for checking Physical Dimensions.

SEGMENTED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
(6) Inspect the segment.	
(7) Lift the segment and replace the lower internal rounding handling-ring, then remove the external rounding-handling rings.	
(8) Provide weather protection for in-plant handling and move the segment to Storage.	Weather Protection.
b. <u>156-Inch Diameter Segment.</u> With the segment in the horizontal attitude, as received from the propellant curing area, the following operations will be performed:	
(1) Install the external rounding rings to each end of the segment.	Transport Dolly—150-ton Cap.
(2) Transfer the segment weight from the internal rounding-handling rings to the external rounding rings.	Support Cradle - (Figure 7-1 page 7-5) 150-ton overhead crane (see Section 8).
(3) Remove the forward and aft internal rounding-handling rings from the segment.	Breakover Stand 25-ton mobile hoist-hoist slings.
(4) Inspect the segment and replace the internal rounding-handling rings for each end.	
(5) Remove the external rounding rings.	Inspection Platform (Figure 5-9 , page 5-27. Radiographic Linac (see Section 10). Ultrasonic Inspection system. Equipment for checking Physical Dimensions. Weather Protection.
(6) Provide weather protection and move to Storage.	
c. <u>Forward and Aft Closures.</u> After removal of all propellant casting equipment, it will be assumed that the closure consists of a propellant-loaded case with attach joint internal rounding-handling and stub skirt handling rings installed.	
(1) With the attach joint up, install an external rounding ring to the attach joint end of the closure.	
(2) Remove the internal rounding-handling ring and inspect the closure.	For the 120-inch closure see paragraph 5, a, , page 6-2

SEGMENTED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
(3) Replace the internal rounding-handling ring and remove the external rounding ring. (4) Provide weather protection and move to Storage.	For the 156-inch closure see paragraph 5, b, page 6-3
6. SEGMENT AND CLOSURE STORAGE. This building provides for the conditioned storage of segments and closures.	
(1) Remove weather protection.	Weather Protection.
(2) Secure component (tie down) and ground.	Transport Dolly - (Figure 7-2A page 7-6).
(3) Store until needed.	Roller Rack - (Figure 5-7A page 5-19).
(4) When required, install weather protection and move the segments and closures to the Packaging and Shipping Area.	Tie Downs. For concepts - see Figures 5-7 and 5-8 pages 5-19 and 5-20.
7. IGNITER SUBASSEMBLY AND INSPECTION.	
a. Igniter Propellant Cartridge. Inspect cartridge, provide weather protection and move to Subassembly area or to Storage.	Igniter cartridge transport dolly. Weather Protection.
b. Igniter Motor Assembly. (1) Receive the igniter motor hardware (case and closure) from inert storage.	Igniter Motor Transport Dolly.
(2) Install the propellant cartridge into the igniter motor case. (3) Assemble the igniter closure to the case.	Slings - hoists.
(4) Provide a weather seal for the S&A attach boss and nozzle openings. (5) Move the igniter motor assembly to storage or provide weather protection for movement to the Packaging and Shipping Area. NOTE: The functional areas required for igniters will depend on the type and number of igniters used. It is envisioned that any type of igniter will create similar functional area requirements.	Weather Protection.

SEGMENTED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
8. <u>IGNITER STORAGE.</u>	
a. <u>Igniter Propellant Cartridge.</u> Remove weather protection, secure (tie down) cartridge and store until needed for assembly with the igniter motor hardware.	Igniter Cartridge Transport Dolly tie-downs. Weather Protection.
b. <u>Igniter Motor Assembly.</u> Remove weather protection, secure (tie down) Igniter Assembly and store until it is required at either the static test or launch site, then transfer to Packaging.	Igniter Assembly Transport Dolly. Weather Protection.
9. <u>NOZZLE-TVC ASSEMBLY AND INSPECTION.</u> The TVC system components and motor nozzle are received from the inert hardware receiving, inspection and distribution area and assembled in this area to form the Nozzle-Liquid TVC subassembly and the tankage and pressure regulator assembly. It appears that the functions required to perform these assembly operations will not require special AGE other than previously discussed.	
<u>NOTE 1)</u> The functional areas required for the TVC system will depend on the type of system used. However, any TVC system will create similar functional areas or requirements. See paragraph (b) , page 6-5 for additional discussion.	
<u>NOTE 2)</u> The only physical attachment between the nozzle-TVC subassembly and the tankage assembly is the main liquid feed line, therefore these two components will require individual structural support which will simulate flight position and attitude.	
(1) Conduct a leak test on the tankage and pressure regulator assembly. Check the nozzle-TVC subassembly (without fluid) to verify system performance.	Checkout Equipment (not included in this effort).
(2) The Nozzle-TVC subassembly and the tankage and pressure regulator assembly are then assembled.	Transport Dolly and Special Support Structure. 5-ton Hoist (120-inch segment) 15-ton Hoist (156-inch segment)
(3) Weather protection for inter-plant handling will be provided and the assembly will be moved to the TVC Functional checkout area.	Weather Protection.

SEGMENTED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
10. <u>NOZZLE TVC FUNCTIONAL CHECKOUT.</u> This area has the capability for full functional checkout of the Nozzle-TVC System before shipment to either the static test or launch site.	
(1) Remove the weather protection for in-plant handling and install the Nozzle-TVC System in the test bay.	Weather Protection.
(2) Fill and charge the fluid and pressurization tanks. A compatible, inert, non-toxic fluid could be used - otherwise special equipment and test area will be required.	Transport Dolly and Special Support Structure.
(3) Conduct cold flow tests.	5-ton hoist(120-inch motor) 15-ton hoist(156-inch motor) Checkout Equipment (Not included in this effort).
(4) Clean and purge the system and disconnect it from the test bay.	
(5) Reinstall weather protection for in-plant handling and move the assembly either to Storage or to Packing and Shipping Area.	
11. <u>NOZZLE-TVC STORAGE PACKING AND SHIPPING.</u> The Nozzle-TVC assembly is stored, packaged and prepared for shipment in this building. The following operations are performed:	
(1) Remove in-plant weather protection and store the assembly.	Special Nozzle/TVC Shipping Container. (For additional equipment see paragraph 9, page 6-5
(2) Install necessary instrumentation and package the assembly for shipment to either the static test or launch site.	
12. <u>PYROTECHNIC SYSTEMS RECEIVING INSPECTION AND SHIPPING.</u>	
a. <u>General.</u> Pyrotechnics are received, inspected, checked out, and prepared for shipment in this building.	
b. <u>Safe and Arm Assembly.</u> The safe and arm assembly is unpacked, inspected and checked out in this area.	Special Packaging.
c. <u>Shaped Charges and Detonating Fuse Transfer and Jumper Harnesses.</u> (1) Unpackage and inspect the assembly. Repackage the assembly and move to the Pyrotechnic Storage Area for storage.	

SEGMENTED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
13. PYROTECHNIC SYSTEMS STORAGE. This building provides conditioned storage for the pyrotechnic assemblies.	
14. PACKAGING AND SHIPPING. Components containing propellants are packaged and prepared for shipping in this area.	Transport Dolly. Two 25-ton mobile hoists.
a. Receiving and Inspection from Storage. (1) Remove in-plant weather protection from the segments, forward and aft closures and igniters. (2) Visually inspect the components prior to packaging.	Weather Protection. Shipping Containers. 50-ton Overhead Crane (120-inch segment) 150-ton Overhead Crane (156-inch segment) Two 5-ton Mobile Hoists
b. Packaging. (1) Install necessary instrumentation and package the components for shipment to either the static test or launch site.	
c. On-Loading to Prime Transporter. Transportation will be accomplished via truck, rail or water. For details on transportation modes and equipment, refer to Section 9.	For loading concepts, refer to Figures 5-2 through 5-5 pages 5-14 through 5-17

c. Static Test Site.

Figure 6-31, page 6-76 shows major motor component flow and functional areas for receipt of segmented components from the motor processing site through assembly, checkout and test. Figures 6-32 through 6-36, pages 6-77 through 6-81 describe the requirements of each functional area for major motor components at the Static Test Site. The following functional analysis is applicable to both vertical and horizontal static testing, with the exception of thrust vector control (vertical test only), and thrust termination and destruct (horizontal test only). These exceptions are noted in the following discussion.

SEGMENTED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
1. RECEIVING, INSPECTION, SUBASSEMBLY AND DISTRIBUTION. This facility provides for receipt and temporary storage of segments, closures and igniter motor assemblies. These components are unpackaged, inspected and subassembled in this area.	
a. Segments. (1) Unpackage the segments and move them to the inspection area. Handle and inspect the segments without removing their external rounding ring. (2) Move the segment to the subassembly area and install necessary instrumentation. (3) Prepare the segment subassembly. Provide intersite weather protection and move the segments to Storage and Conditioning Area.	120-inch Segment 50-ton overhead crane (See Section 8) Two 5-ton mobile hoists (Figure 7-4D, page 4-7) 156-inch Segment 150 ton overhead crane (See Section 8) Support cradle Breakover stand 25-ton mobile hoist 120/156 inch Segments Shipping containers (Figure 7-1 , page 7-5) Transport Dollies (Figure 7-2 , page 7-6) Hoist slings Radiographic Linac (See Section 10) Inspection Platform (Figure 5-9 , page 5-21) Ultrasonic Inspection System Equipment for checking physical dimensions Weather protection.

SEGMENTED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
	NOTE: 1) **The equipment used will be similar to that used at the motor manufacturing facility.** 2) **It should be emphasized that equipment designed for the 156-inch motor could, with modifications, be used for the 120-inch motor.**
b. <u>Forward Closures.</u> (1) Unpackage the Forward Closure, move it to the inspection area. Handle and inspect the closure without removing its external rounding ring. (2) Move the Closure to the subassembly area. Invert it 180 degrees (igniter boss facing up) for subassembly. Install the igniter motor (received from inspection area) into the closure and secure it in place. (3) Assemble the thrust termination port covers and stacks (received from Inspection area) to the closure. (4) Install necessary instrumentation, then invert the closure 180 degrees. Provide weather protection for intersite handling. Move the closure subassembly to the Storage and Conditioning Area.	Closure Dolly Closure inverting fixture Igniter motor transport dolly Igniter motor insertion fixture NOTE: For additional equipment refer to paragraph 5.c, page 6-47.
c. <u>Aft Closure (120/156-inch Motors).</u> (1) Unpackage the Aft closure and move it to the inspection area. Handle and inspect the aft closure without removing its external rounding ring. (2) Move the closure to the subassembly area and invert it 180 degrees (nozzle boss facing up) for subassembly. (3) Install the Nozzle-TVC assembly (received from the Maintenance, Inspection and Subassembly Area) by inverting it 180 degrees (nozzle closure mating flange down) and securing it to the aft closure. (4) Install necessary instrumentation.	Closure inverting fixture Nozzle/TVC transport dolly and support fixture Nozzle installation fixture NOTE: For additional equipment refer to paragraph 5.c, page 6-47.

SEGMENTED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
(5) Provide weather protection for intersite handling. (6) Prepare the closure subassembly and move it to the Storage and Conditioning Area.	
d. <u>Igniter Motor Assembly.</u> (1) Unpackage the assembly and move it to the inspection area. (2) Remove the igniter closure and perform inspection. (3) Reassemble and move the assembly to either the subassembly area for installation into the forward closure or to the igniter storage area.	Igniter motor transport dolly Hoist slings Weather protection.
2. <u>SEGMENT STORAGE AND CONDITIONING.</u> This facility provides conditioned storage for segments and closures. The requirements for this functional area are in addition to those of the normal storage area because of the closer temperature tolerances (± 5 degrees versus ± 15 degrees) needed for static testing or launching. Temperature cycling of these components (if required) may be accomplished in this area. (1) Receive subassemblies from the Receiving Inspection, Subassembly and Distribution Area. (2) Remove weather protection; secure (tie-down) and ground the components in storage. (3) Store the subassemblies at require temperatures until needed for test, then reassemble the weather protection and move them to the test bay.	Segment and closure transport dollies Weather protection Roller racks (tie-downs) For applicable concepts, see Figures 5-7 and 5-8 , pages 5-19 and 5-20 NOTE: Figure 7-46, page 7-8 shows one version of a portable conditioning unit for a completely assembled motor. This could be desirable for assembled motors scheduled for immediate use.
3. <u>IGNITER STORAGE AND CONDITIONING AREA.</u> This facility provides conditioned storage for the igniter motor assembly. Temperature cycling of these components (if required) may be accomplished in this area. (1) Receive Igniter motor assembly from the Receiving, Inspection, Subassembly and Distribution Area.	Igniter motor transport dollies Weather protection Tie-downs.

SEGMENTED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
(2) Remove weather protection, secure (tie-down) and ground the components in storage.	
(3) Store the components at the required temperature until they are needed for subassembly to the forward closure, then reassemble the weather protection and return them to the Receiving Inspection, Subassembly and Distribution Area.	
4. PYROTECHNIC RECEIVING, INSPECTION AND STORAGE.	
a. Safe and Arm Assemblies.	
(1) Receive assemblies from the motor manufacturing site and unpackage them.	Special Packaging.
(2) Inspect and check out the assemblies.	
(3) Repackage the assemblies and move them to the Storage area.	
(4) When needed, move the igniter safe and arm assembly only to the vertical test bay.	
b. Shaped Charges and Detonating Fuse Transfer and Jumper Harnesses (For Horizontal Test Only).	
(1) Receive components from the motor manufacturing site and unpackage. Inspect, repackage and move them to Pyrotechnic Storage.	Special Packaging.
(2) When needed, move the thrust termination and destruct system to the horizontal test bay.	
5. MAINTENANCE, INSPECTION, SUBASSEMBLY AND STORAGE.	
All inert parts and components are received from the motor manufacturing site and unpackaged, inspected, and stored in this building until needed. The Nozzle-TVC assembly which was previously assembled at the Nozzle/TVC Assembly and Inspection Area of the motor processing site is checked out, cold-flow tested, and stored as an assembly in this building. The TVC system is a major subassembly requiring a functional checkout in this area. The basic requirements for this system are discussed below.	

SEGMENTED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
a. Nozzle-Liquid TVC Assembly Including Tankage and Pressure Regulator. (1) Receive the assembly from the motor manufacturing site and unpackage. (2) Inspect and leak test the tankage and pressure regulator assembly. (3) Check out (without injectant fluid). (4) Provide weather protection and move the assembly to the cold flow test bay. (5) Remove weather protection and install the assembly in the test bay. (6) Fill and charge the fluid pressurization tanks. (7) Conduct the cold-flow test and check out the system. (8) Monitor the test in accordance with checkout requirements outlined under "Ground Instrumentation Requirements", Figure 6-24 Page 6-43. (9) Following the cold flow functional test, clean and purge system and disconnect from the test bay. (10) Provide weather protection and move the assembly back to the storage area until it is needed for subassembly to the aft closure. (11) When needed, move the assembly to the Receiving, Inspection Subassembly and Distribution Area.	Checkout equipment (not included in this effort) transport dolly and special support structure. 5-ton hoist (120-inch motor) 15-ton hoist (156-inch motor) Weather Protection. NOTE: The cold flow test will consist of using an inert compatible gas or liquid to determine functional capability of the system. Valve responses and flow leaks will be a major concern. A gimble or jet tab TVC system would require a measuring device to determine the degree of gimbling or tab movement.
b. Thrust Termination Port Covers and Stacks. (1) Receive the components from the motor manufacturing site and unpackage them. (2) Inspect and move them to the storage area. (3) Add weather protection and move the components to the Receiving, Inspection Distribution and Subassembly Area.	Weather protection.

SEGMENTED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT

6. STATIC TEST

a. Vertical Test Bay.
This facility provides for assembly, servicing, checkout, conditioning, and test of the complete rocket motor in the inverted position with nozzle up. (Destruct and thrust termination tests will not be accomplished at this facility). It has been assumed that the actual destruct and thrust termination tests will be conducted at another area.

(1) Motor Assembly.

(a) Lift the forward closure subassembly and remove the handling ring from the stub skirt.

(b) Install the forward closure subassembly and secure it to the test bay. Remove the internal rounding-handling ring from the attach joint.

(c) In the case of the 120-inch segment, lift the subassembly (external rings installed) and remove the lower internal rounding-handling ring.

(d) In the case of the 156-inch segment, tilt the subassembly (external rounding rings installed) to the vertical and remove the lower internal rounding-handling ring.

(e) Mate and assemble the segment subassembly to the forward closure subassembly. Remove the lower external and upper internal rounding-handling rings from the segment.

(f) Repeat the procedure for the other segments described above.

(g) Lift the aft closure subassembly and remove the internal rounding-handling ring. Mate and assemble it to the segment subassembly. Secure the aft closure subassembly to the test bay and remove the remaining external rounding rings from the motor case.

Suggested Equipment:

120-inch Segment
5-ton Mobile hoist
50-ton Crane (See Section 8)
5-ton Auxiliary Hoist

156-inch Segment
10-ton Auxiliary Hoist
Breakover Stand
25-ton Mobile Hoist
Support Cradle
150-ton Crane (See Section 8)

120/156-inch Segment
Hoist Slings
Environmental Protection
Special Support Structure for Nozzle-TVC System
Portable Work Platforms
Motor Support Structure
Test Equipment (not included in this effort)
Pressure Source
Leak Detector
Assembly Equipment
Transport Dollies (Figure 7-2, page 7-6)

SEGMENTED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
(2) Static Checkout. (a) Install a sealing device over the motor nozzle and Safe and Arm opening and perform a leak check. Remove sealing devices. Fill and charge the TVC fluid and pressurization tanks. (b) Provide environmental protection and install the Safe and Arm assembly to the igniter motor. (c) Install the final instrumentation; conduct final checkout and static test.	Propellant handling equipment for liquid injection. Purging and decontamination equipment for toxic propellants. Test equipment (not included in this effort). Pressure Source. Leak Detector.
(3) Test. To provide for a satisfactory evaluation of motor performance throughout development and flight tests, there will be requirements to monitor, record, and evaluate certain motor parameters. Figure 6-24, page 6-43 indicates those parameters applicable to static testing of the assembled rocket motor.	
(4) Disassembly. Disassembly of the motor follows a procedure which is the reverse of paragraph (1), page 6-57.	Disassembly equipment. NOTE: For additional equipment, refer to paragraph(1) page 6-57. Purging & Decontamination Equipment & Supplies for TVC System Component Transport Dollies Weather Protection
(5) Distribution of Parts to Maintenance Facility. Return the disassembled motor components to the Maintenance, Inspection and Subassembly area for packing and return shipment to the motor manufacturing facility.	
b. Horizontal Test Bay. This facility provies for assembly, servicing, checkout, conditioning and test of a complete rocket motor in the horizontal position. It appears that any preliminary destruct or thrust termination test would be conducted in this attitude. TVC data would be compromised, but could be calculated.	

SEGMENTED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
The sequence of motor assembly, with the exception of thrust vector control system servicing and checkout, is as follows:	
(1) Motor Assembly. (a) Repeat steps 1) through 6) as described for the Vertical Test Bay, page 6-57 (b) Mate the aft closure subassembly and assemble it to the segment subassembly. Remove the remaining external rounding rings from the motor case. (c) Tilt the assembled rocket motor from vertical to horizontal position and secure. (The assembled rocket motor, supported at the forward and aft closure attach joints, is capable of withstanding those bending moments discussed under "Design Characteristics", (Paragraph (4), page 6-10). NOTE: The motor can also be assembled horizontally. This would require less lifting equipment since tilting from vertical to horizontal position is not required. Horizontal alignment and positive segment joint fitting would, however, require special techniques and equipment.	120-inch Segment Two 140-ton Crawler Cranes Two 5-ton Mobile Hoists 156-inch Segment 500-ton Bridge Crane Two 25-ton Mobile Hoists 120/156-inch Segments Transport Dollies (Figure 7-2, page 7-6). Environmental Protection. Portable Work Platforms. Motor Support Structure. Assembly Equipment. NOTE: The equipment required for the 156-inch segment can also support the 120-inch segment.
(2) Static Checkout. (a) Install a sealing device over the motor nozzle and Safe and Arm opening. Perform the leak check and then remove the sealing devices. Install environmental protection. (b) Install the Safe and Arm assembly into the igniter motor. Install the thrust termination and destruct system Safe and Arm assemblies to their respective places on the forward closure. (c) Install shaped charges to the thrust termination port covers and motor case segments. (d) Connect all transfer harness connections to their respective Safe and Arm assemblies. (e) Install the final instrumentation and perform final checkout. Conduct static test.	Pressure Source. Leak Detector.

SEGMENTED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
(3) Test. To provide for a satisfactory evaluation of motor performance throughout development and flight tests, there will be requirements to monitor, record, and evaluate certain motor parameters. Figure 6-24, page 6-43. indicates those parameters applicable to static testing of the assembled rocket motor.	
(4) Disassembly. Disassembly of the motor follows a procedure which is the reverse of paragraph (1) page 6-59	Disassembly equipment. NOTE: For additional equipment refer to paragraph (1), page 6-59
(5) Distribution of Parts to Maintenance Facility. Return disassembled motor components to the Maintenance, Inspection Subassembly area for packing and return shipment to the motor manufacturing facility.	Component Transport Dollies Weather Protection

d. Launch Site.

Figure 6-37, page 6-82 shows the major motor component flow and functional areas from receipt of the components from the motor manufacturing site through assembly and checkout at the launch pad.

Figures 6-38 through 6-42, pages 6-43 through 6-87 describe the functional requirements at each area for the major motor components at the launch site.

Two final vehicle assembly concepts are considered as follows:

1) The Universal Pad Concept (all assembly operations are performed on the launch pad).

2) The Integrated Transfer and Launch Concept. (All assembly operations are performed off the launch pad). Mating of solid and liquid stages occurs at an intermediate mating station from which the complete vehicle is transported to the launch pad.

The functional analysis presented below is applicable to both concepts to the point of final assembly of the vehicle.

NOTE: The discussion of handling of the 120-inch and 156-inch segmentized motors is predicated on the concepts envisioned for the 624A system. (Two segmented solid motors strapped to a liquid core). See Figure 5-13, page 5-25. For booster and vehicle configurations other than those used in the 624A type system (Figure 5-13, page 5-25) final vehicle assembly concepts would change.

SEGMENTED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
1. RECEIVING, INSPECTION, SUBASSEMBLY AND DISTRIBUTION. This facility provides for receipt and temporary storage of segments, closures and igniter motor assemblies. These components are unpackaged, inspected and subassembled in this area.	
a. Segments. (1) Unpackage the segment and move it to the inspection area, handle and inspect the segment without removing its external rounding ring. (2) Move the segment to the subassembly area and install necessary instrumentation. (3) Prepare the segment subassembly. Provide intersite weather protection, and move the segment to the Storage and Conditioning Area.	120-inch Segment 50-ton Overhead Crane (See Section 8). 5-ton Mobile Hoist (Figure 7-4D, page 7-8). 156-inch Segment 150-ton Overhead Crane. Support Cradle. Breakover Stand. 120/156-inch Segments Shipping Containers (Figure 7-1 , page 7-5). Transport Dollies (Figure 7-2 , page 7-6). Hoist Slings. Radiographic Linac (See Section 10). Inspection Platform (Figure 5-9 , page 5-21). Ultrasonic Inspection System. Equipment for checking physical dimensions. Weather protection. NOTE: 1) The equipment used will be similar to that used at the motor manufacturing facility. 2) It should be emphasized that equipment designed for the 156-inch motor could, with modifications, be used for the 120-inch motor.

SEGMENTED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
	It appears that the roller rack concept offers the greatest potential for land carriers. (See Figure 7-3 page 7-7 . Cranes will be required to accomplish loading and off-loading from water carriers.
b. Forward Closures. (120/156-Inch Motors) (1) Unpackage the Forward Closure, move to the inspection area. Handle and inspect the closure without removing external rounding ring. (2) Move the closure to the subassembly area, invert it 180 degrees (igniter boss facing up) for subassembly. Install the igniter motor (received from inspection area) into the closure and secure it in place. (3) Assemble the thrust termination port covers and stacks (received from inspection area) to the closure. (4) Install necessary instrumentation. Provide weather protection for intersite handling. Move the closure subassembly to the Storage and Conditioning Area.	Closure Dolly. Closure Inverting Fixture Igniter Motor Transport Dolly. Igniter Insertion Fixture. NOTE: For additional equipment, refer to paragraph a, page 6-62
c. Aft Closure (120/156-inch Motors). (1) Unpackage the Aft closure, move it to the inspection area. Handle and inspect the closure without removing its external rounding ring. (2) Move the closure to the subassembly area and invert it 180 degrees (nozzle boss facing up) for subassembly. (3) Install the Nozzle-TVC assembly (received from the Maintenance Inspection and Subassembly Area) by inverting it 180 degrees, (Nozzle closure mating flange down) and securing it to the aft closure. (4) Install necessary instrumentation.	Closure Dolly. Closure Inverting Fixture. Nozzle/TVC Transport Dolly and Support Fixture. Nozzle Installation Fixture. NOTE: For additional equipment, refer to paragraph a, page 6-62.

SEGMENTED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
(5) Provide weather protection for intersite handling. (6) Prepare the closure subassembly and move it to the Storage and Conditioning Area.	
d. <u>Igniter Motor Assembly.</u> (1) Unpackage the Assembly and move it to the inspection area. (2) Remove the igniter closure and perform inspection. (3) Reassemble and move the assembly to either the subassembly area for installation into the forward closure or to the igniter storage area.	Igniter Motor Transport Dolly. Hoist Slings. Weather Protection.
2. <u>SEGMENT STORAGE AND CONDITIONING.</u> This facility provides conditioned storage for segments and forward and aft closures. The requirements for this functional area are in addition to those of the normal storage area because of the closer temperature tolerances (± 5 degrees versus ± 15 degrees) needed for static testing or launching. (1) Receive the subassemblies from the Receiving, Inspecting Subassembly and Distribution Area. (2) Remove weather protection, secure (tie down) and ground the components in storage. (3) Store the subassemblies at the required temperatures until needed at either the solid assembly building or launch pad.	Segment & closure transport dollies. Weather Protection. Roller Racks - tie downs. For applicable concepts, see Figures 5-7 and 5-8 , pages 5-19 and 5-20 NOTE: Figure 7-46, page 7-8 shows one version of a portable conditioning unit for a completely assembled motor. This could be desirable for assembled motors scheduled for immediate use.
3. <u>IGNITER STORAGE & CONDITIONING AREA.</u> This facility provides conditioned storage for the igniter motor assembly. Temperature cycling of these components (if required) may be accomplished in this area.	Igniter motor transport dollies. Weather Protection. Tie-downs.

SEGMENTED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
(1) Receive igniter motor assembly from the Receiving, Inspection, Subassembly and Distribution Area.	
(2) Remove weather protection, secure (tie-down) and ground the components in storage.	
(3) Store the components at the required temperature until needed for subassembly to the forward closure, then reassemble the weather protection and return the components to the Receiving Inspection, Subassembly and Distribution Area.	
4. <u>PYROTECHNIC RECEIVING, INSPECTION AND STORAGE.</u>	
a. <u>Safe and Arm Assemblies.</u>	Special Packaging
(1) Receive assemblies from the manufacturer and unpackage.	
(2) Inspect and check out the assemblies.	
(3) Repackage assemblies and move them to the Storage area.	
(4) When needed, move the assemblies to the launch pad.	
b. <u>Shaped Charges and Detonating Fuse Transfer and Jumper Harnesses (for Horizontal Test Only).</u>	Special Packaging
(1) Receive components from the manufacturer and unpackage. Inspect, repackage and move them to Pyrotechnic Storage.	
(2) When needed, move the thrust termination and destruct system to the launch pad.	
5. <u>MAINTENANCE, INSPECTION, SUBASSEMBLY AND STORAGE.</u>	
All inert parts and components are received from the motor manufacturing site, unpackaged, inspected, and stored in this building until needed. The Nozzle/TVC assembly which was previously assembled at the Nozzle/TVC Assembly and Inspection Area of the motor processing site is checked out, cold-flow tested, : stored as an assembly in this building. The TVC system is a major subassembly requiring functional checkout in this area. The basic requirements for this system are discussed below.	

SEGMENTED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
(1) Receive the assembly from the motor manufacturing site and unpackage it.	Leak Detector.
(2) Inspect and leak test the tankage and pressure regulator assembly.	Test Equipment (not included in this effort).
(3) Checkout (without injectant fluid).	Transport Dolly and special support structure.
(4) Provide weather protection and move the assembly to cold flow test bay.	5-ton Hoist (120-inch motor). 15-ton Hoist (156-inch motor).
(5) Remove weather protection and install the assembly in the test bay.	Weather Protection.
(6) Fill and charge the fluid pressurization tanks.	NOTE: The cold-flow test will consist of using an inert compatible gas or liquid to determine functional capability of the system. Valve responses and flow leaks will be a major concern. A gimble or jet tab TVC system would require a measuring device to determine the degree of gimbling or tab movement.
(7) Conduct the cold-flow test and checkout the system.	
(8) Monitor the test in accordance with checkout requirements outlined, under "Ground Instrumentation Requirements, Figure 6-24 page 6-43.	
(9) Following cold-flow functional test, clean and purge system and disconnect it from the test bay.	
(10) Provide weather protection and move the assembly back to storage area until it is needed for subassembly to the aft closure.	
(11) When needed, move the assembly to Receiving, Inspection Subassembly and Distribution Area.	
b. Thrust Termination Port Covers and Stacks.	
(1) Receive the components from the motor manufacturing site and package them.	
(2) Inspect and move them to the storage area.	
(3) Add weather protection and transfer to the Receiving, Inspection Subassembly and Distribution Area.	Weather protection.
6. MOTOR VEHICLE ASSEMBLY.	
a. Integrated Transfer & Launch Technique.	
(1) Solid Motor Assembly Building. This area provides facilities for vertical (flight attitude) assembly and checkout of of solid rocket motors, except for the	

pyrotechnics. Conditioned holding areas are provided for storing motor segments and closure subassemblies. Facilities are also provided for integrating the solid rocket motors with the vehicles in which they are used. The sequence of motor assembly, checkout, and integration is as follows:

(a) Receive the segment and closure subassemblies from the Ready Motor Storage Building.
(b) Remove weather protection.
(c) Invert the aft closure subassembly 180 degrees (motor nozzle down).
(d) Remove the handling ring from the closure sub skirt.
(e) Install the aft closure subassembly and secure it to the motor assembly stand.
(f) Remove the internal rounding-handling ring from the closure attach joint.
(g) For the 120-inch segment (external rounding rings installed), lift the subassembly and remove the lower internal, rounding-handling ring.
(h) For the 156-inch segment, the procedure is the same as above, except that the subassembly must first be rotated to a vertical attitude.
(i) Mate the segment subassembly and assemble it to the aft closure subassembly.
(j) Remove the lower external and upper internal rounding-handling rings.
(k) Repeat the operative subsequent segment assemblies.
(l) Lift the Forward closure subassembly and remove the internal rounding-handling ring from the attach joint. Mate this subassembly to the segment subassembly and remove the remaining external rounding rings from the motor case.

<u>120-inch Segments</u>
50-ton Crane
25-ton Auxiliary Crane
5-ton Mobile Hoist

<u>156-inch Segments</u>
150-ton Crane
75-ton Auxiliary Crane
25-ton Mobile Hoist

<u>120/156-ton Segment</u>
Transport Dollies
Support Cradle
Hoist Slings
Special Support Structure for Nozzle TVC System
Moveable Work Platforms
Pressure Source
Leak Detector
Individual Motor Transporters (Figure 5-12, page 5-24
Equipment for Assembly and Disassembly

NOTE: Equipment for assembling completed solid motors into boosters or to liquid cores depends upon the particular vehicle considered and the mating concept employed. See Figures 5-12 and 5-13, pages 5-24 and 5-25 for applicable concepts.

SEGMENTED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
(m) Install sealing device into the nozzle throat entrance and Safe and Arm opening. Perform a leak check then remove the sealing devices. Perform preliminary checkout. Integrate the solid rocket motor with the launch vehicle and move the vehicle to the Launch Pad (ITL). Provide environmental protection for the solid rocket motors.	Individual motor transporters may employ crawlers, rubber tires, or rail-supported wheels. Approximate weights would be as follows: for 120-inch motor, 6 segments - 600,000 lbs. For 156-inch motor, 5 segments - 1.5 million lbs. Selection of transporter type must include consideration of facility implications (rails, roads, etc.) Transporter designs must take into consideration mating of the solid motors with the liquid core. Environmental Protection (possibly similar to Figure 7-4C, page 7-8) for Complete Solid Motor. Test equipment not included in this effort.
(2) Launch Pad Operations. This facility accepts a completely integrated vehicle and prepares it for final checkout and launch. The sequence of final assembly, checkout, conditioning and test is as follows: (a) Service TVC fluid and pressurization tanks. (b) Install transfer harness and shaped charges on the thrust termination port covers and the shaped charges, transfer and jumper harnesses on the motor segments. (c) Install final instrumentation. (d) Install thrust termination and destruct system and Safe and Arm assemblies into their respective places on the forward closure. (c) Install igniter Safe and Arm assembly into the igniter motor and make all transfer harness connections to their respective Safe and Arm assemblies as well as jumper harness connections between segment destruct charges. After final checkout, the solid rocket motor is ready for launch.	NOTE: Any equipment used for this operation is a function of the assembly concept used. For pertinent concepts see Section 5. Figure 5-13, page 5-25 Environmental Protection TVC Fluid Filling Equipment (not included in this effort). Applicable Work Platforms and Lighting Equipment for Installation of Ignition and Destruct System. NOTE: In most instances only equipment for the 156-inch Motor could, with modifications, be used for the 120-inch Motor.

SEGMENTED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
b. Universal Launch Pad Technique. This facility provides for the vertical assembly, checkout and mating of solid rocket motors to the vehicle on the launch pad. The sequence of motor assembly, checkout and mating are as follows: Proceed as described under Solid Motor Assembly (ITL concept) until the solid rocket motor is integrated with the launch vehicle. (See Paragraph 6 a) (1), page 6-66 . Then continue with steps outlined under Launch Pad (ITL). (See Paragraph 6 a) (2), page 6-68 .	The equipment required is similar to that of Paragraph 6 a) (1) and 6 a) (2) with the exception of the Motor Transporter. The gantry itself is considered as a facility rather than as a piece of equipment. For typical Gantry Assembly Concept, see Figure 5-10, page 5-22.

FOR DISCUSSION
REFER TO PAGE 6-45

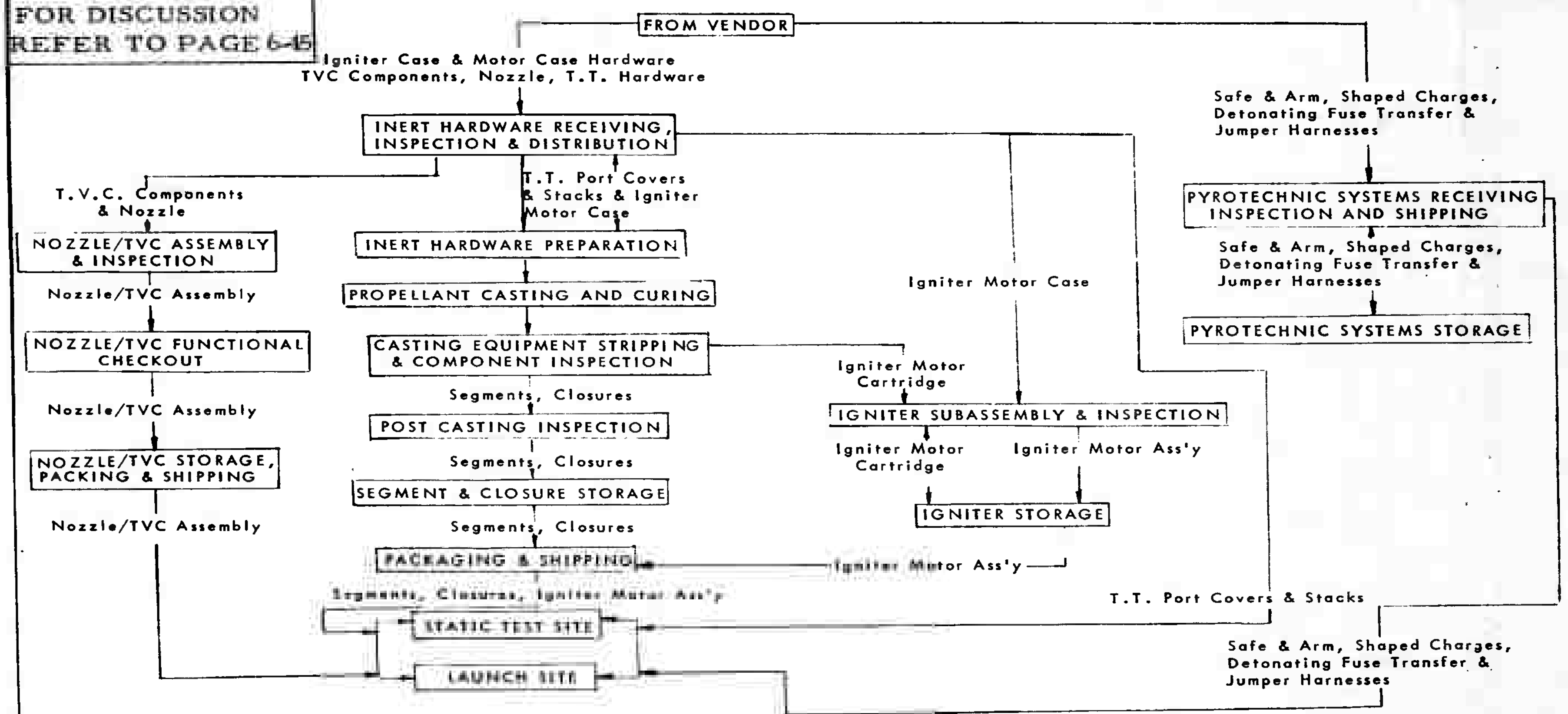


FIGURE 6-25

BASIC FLOW DIAGRAM FOR 120/156 INCH MOTORS AT THE MANUFACTURING SITE

FOR DISCUSSION REFER TO PAGE 6-45

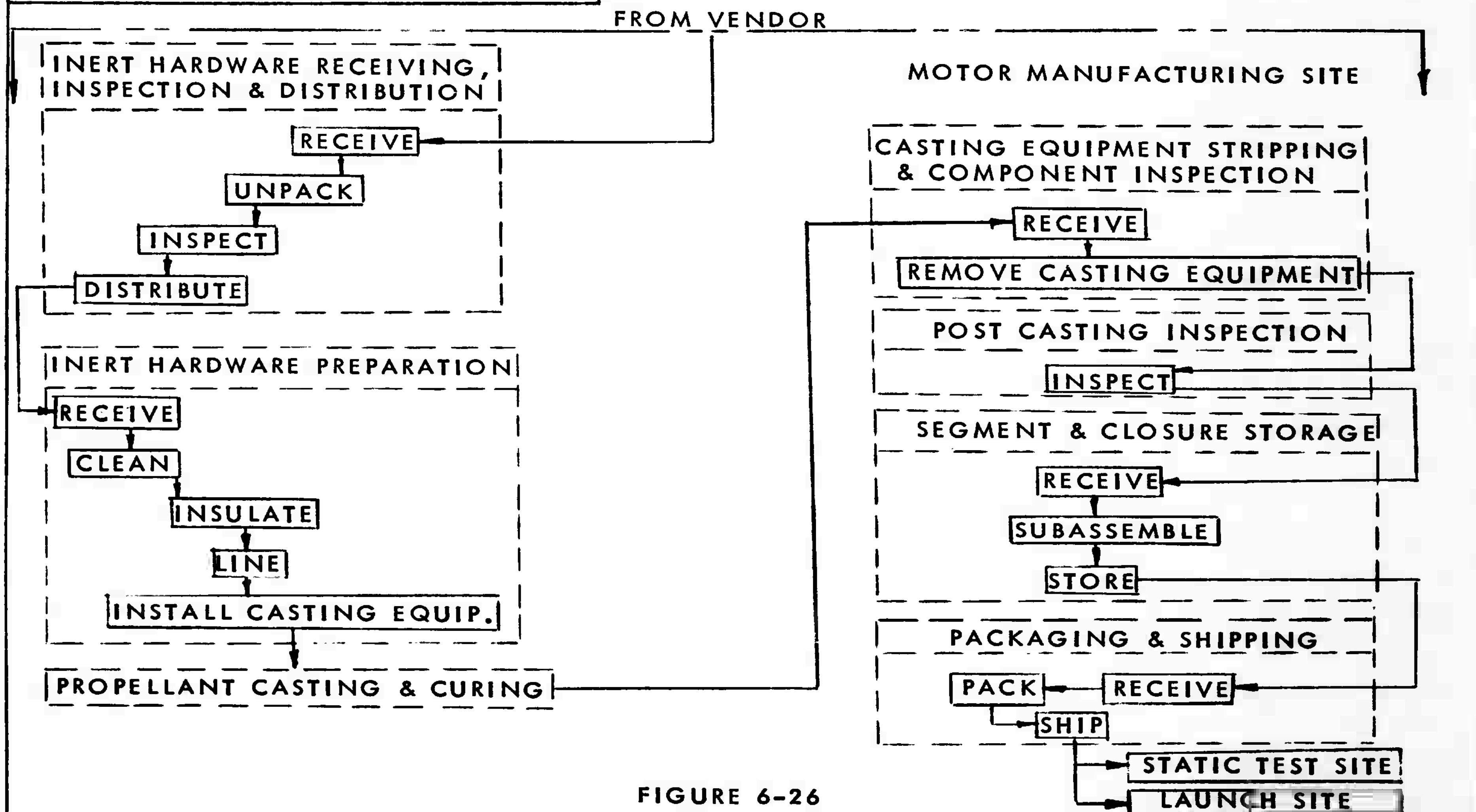


FIGURE 6-26

FUNCTIONAL FLOW CHART FOR 120/156 INCH MOTOR CASE HARDWARE AT THE MOTOR MANUFACTURING SITE

FOR DISCUSSION REFER TO PAGE 6-45

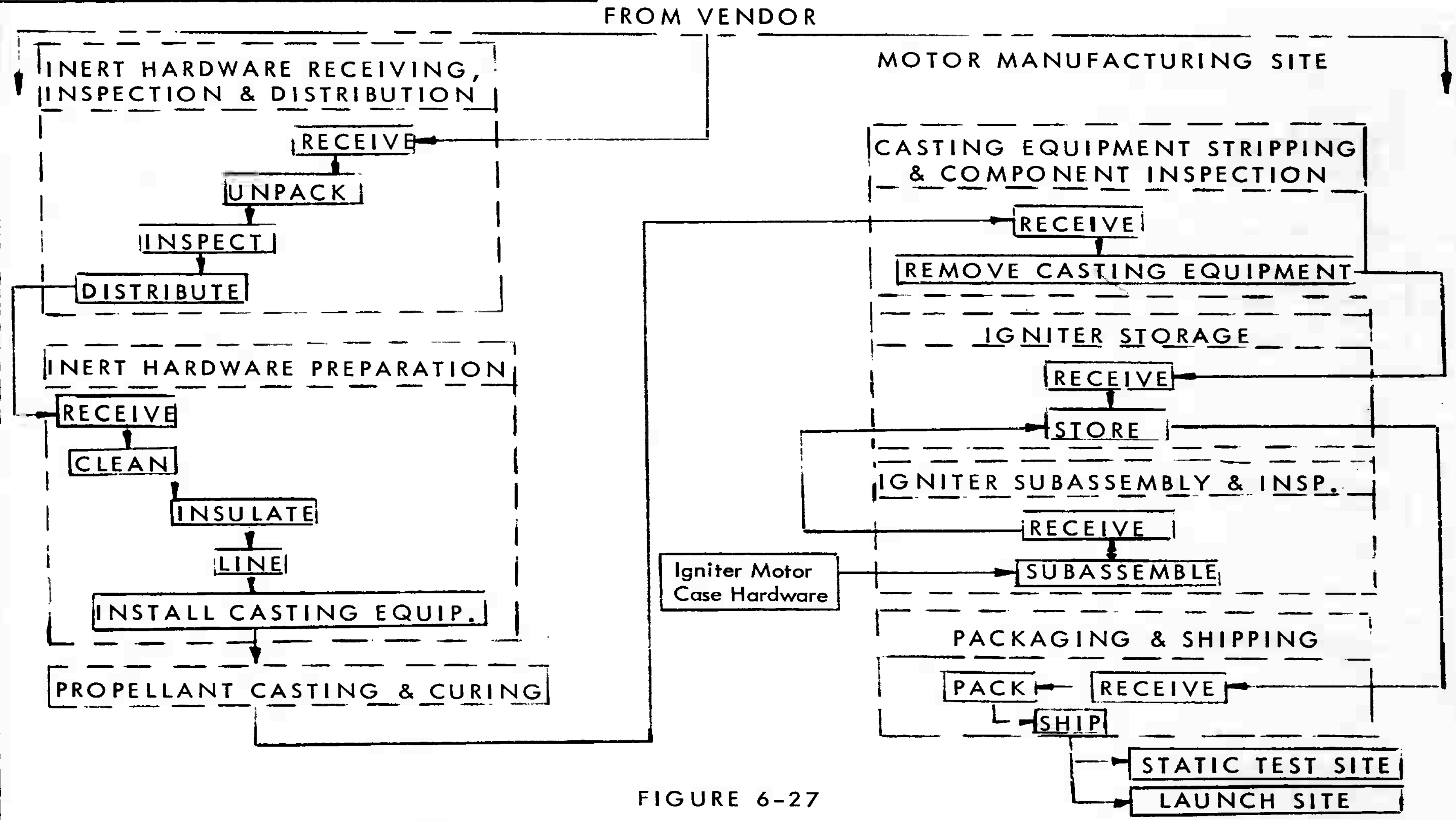


FIGURE 6-27

FUNCTIONAL FLOW CHART FOR 120/156 INCH MOTOR IGNITER MOTOR CARTRIDGE AT THE MOTOR MANUFACTURING SITE

FOR DISCUSSION REFER TO PAGE 6-45

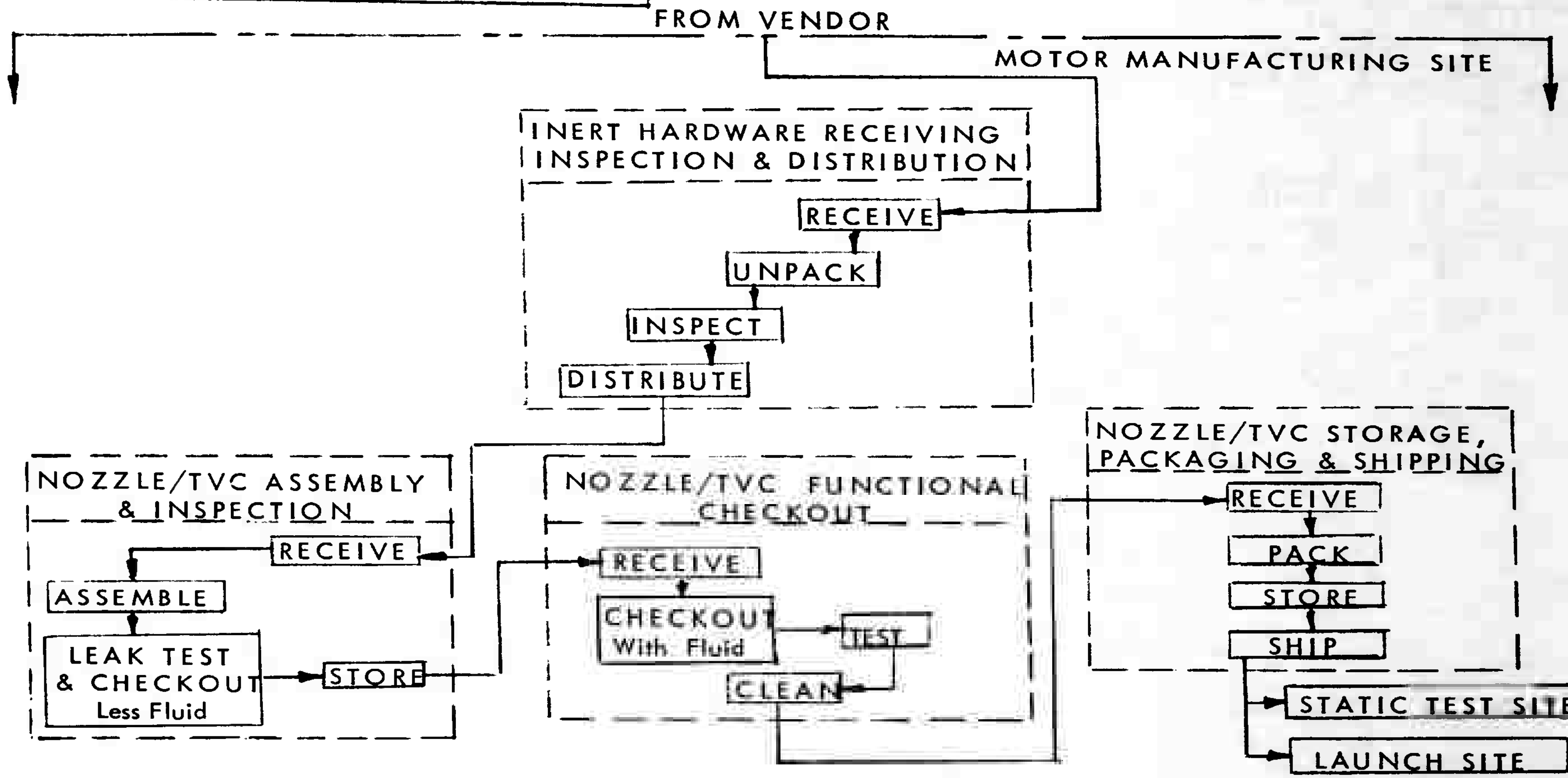


FIGURE 6-28

FUNCTIONAL FLOW CHART FOR 120/156 INCH MOTOR NOZZLE AND T.V.C. COMPONENTS AT THE MOTOR MANUFACTURING SITE

FOR DISCUSSION REFER TO PAGE 6-45

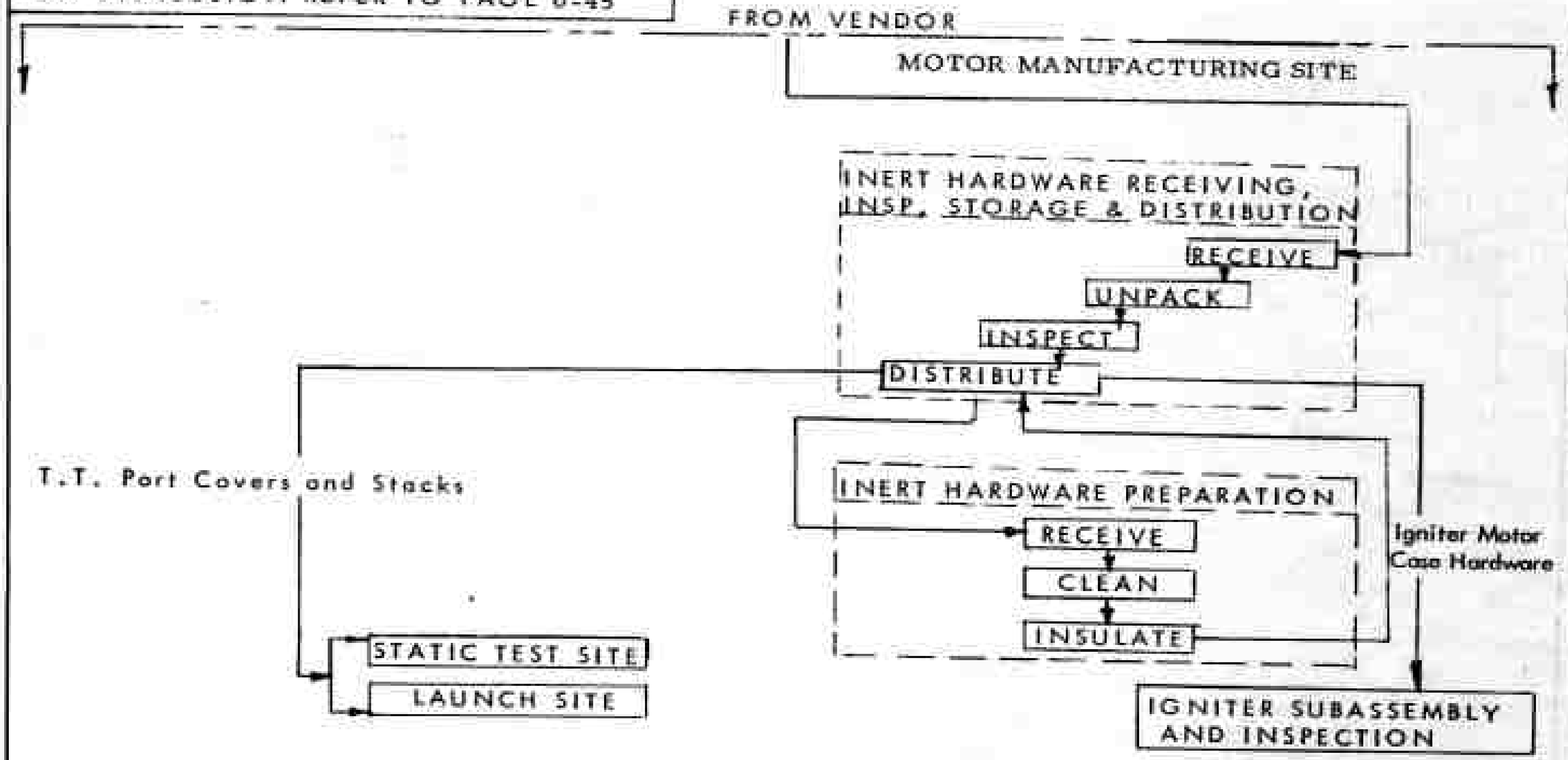


FIGURE 6-29

FUNCTIONAL FLOW CHART FOR 120/156 INCH MOTOR THRUST TERMINATION PORT COVERS & STACKS AND IGNITER MOTOR CASE HARDWARE AT THE MOTOR MANUFACTURING SITE

FOR DISCUSSION REFER TO PAGE 6-45

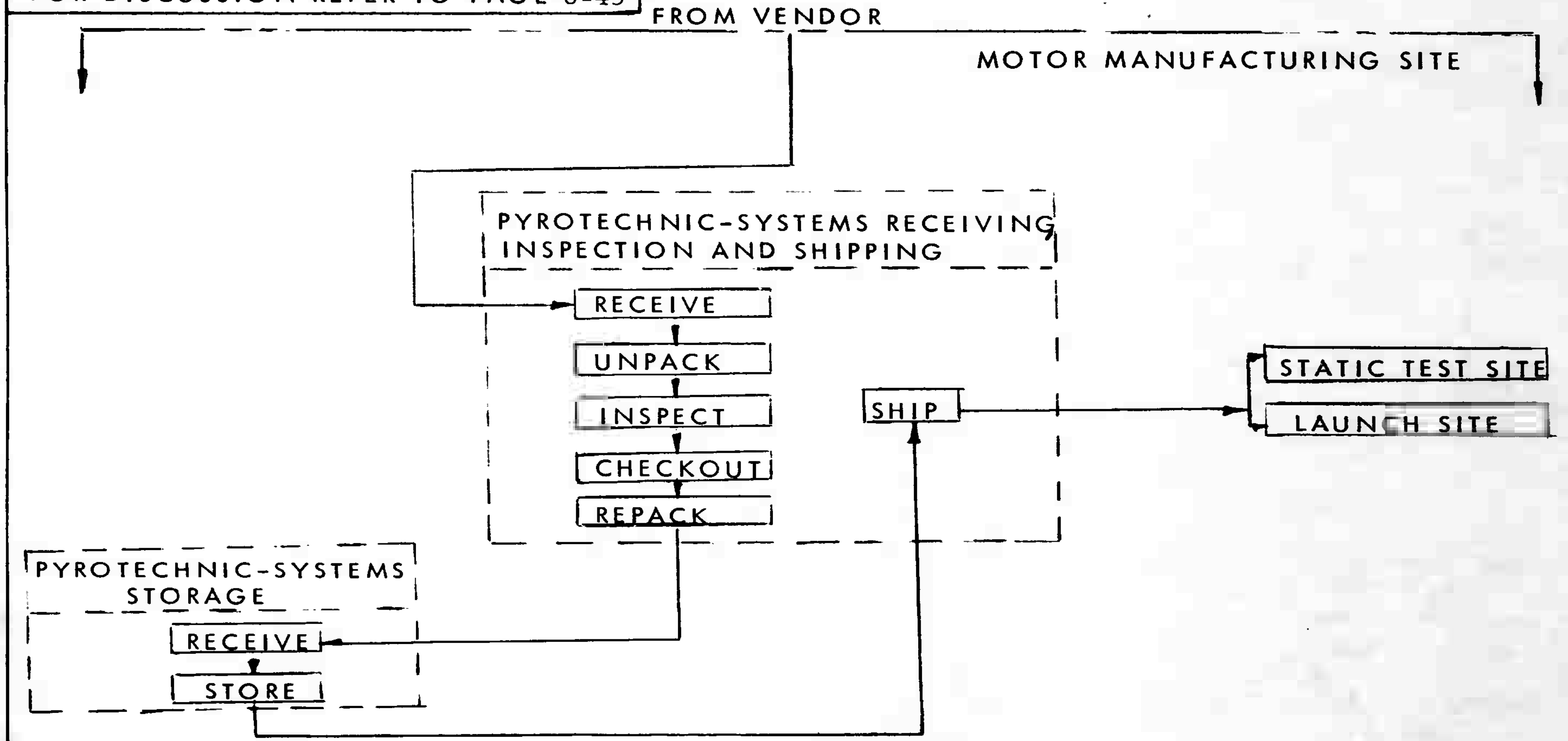


FIGURE 6-30

FUNCTIONAL FLOW CHART FOR 120/156 INCH MOTOR SAFE & ARMS, SHAPED CHARGES AND DETONATING FUSE TRANSFER AND JUMPER HARNESSES AT THE MOTOR MANUFACTURING SITE

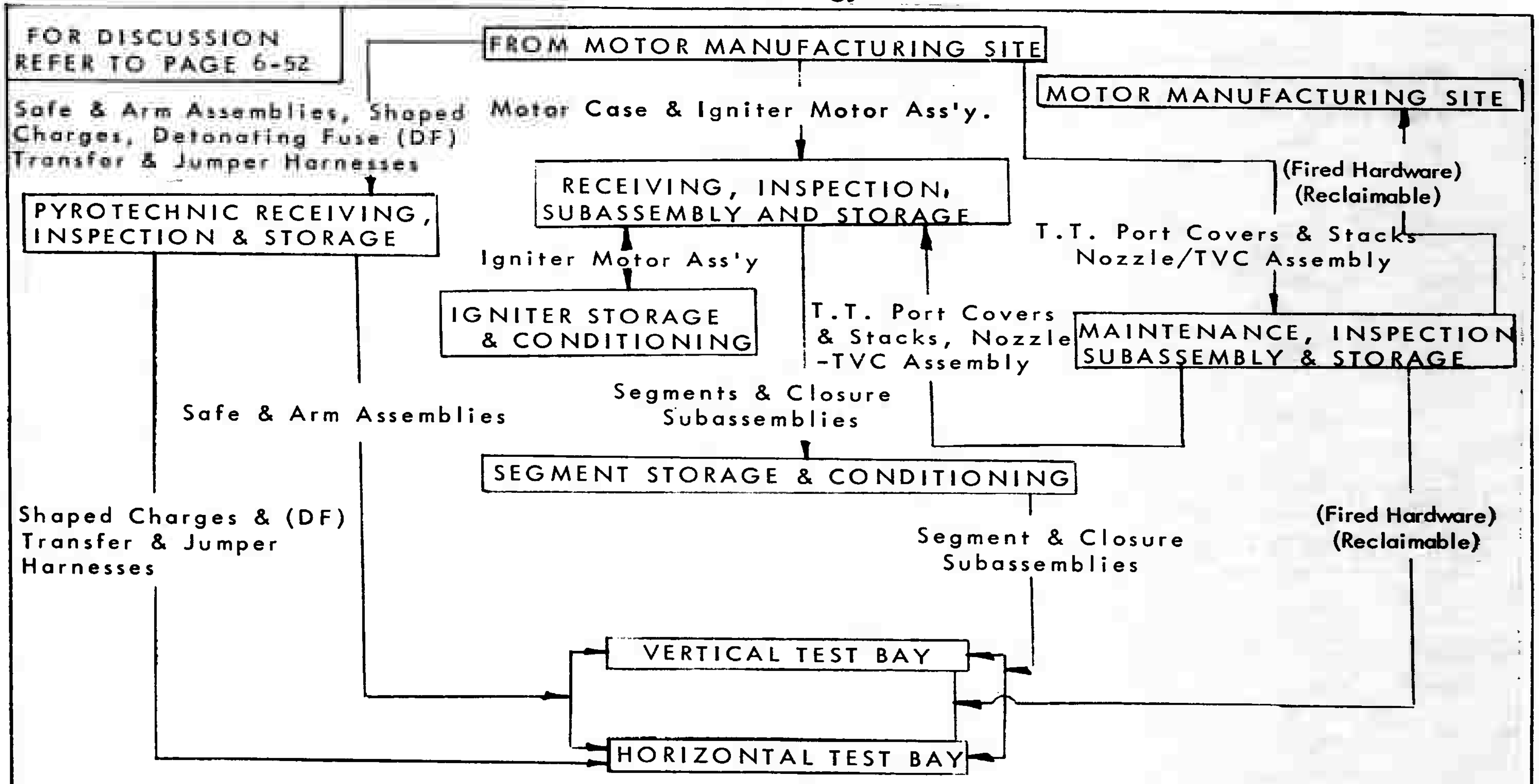


FIGURE 6-31

BASIC FLOW DIAGRAM FOR 120/156 INCH MOTORS AT THE STATIC TEST SITE

FOR DISCUSSION REFER TO PAGE 6-52

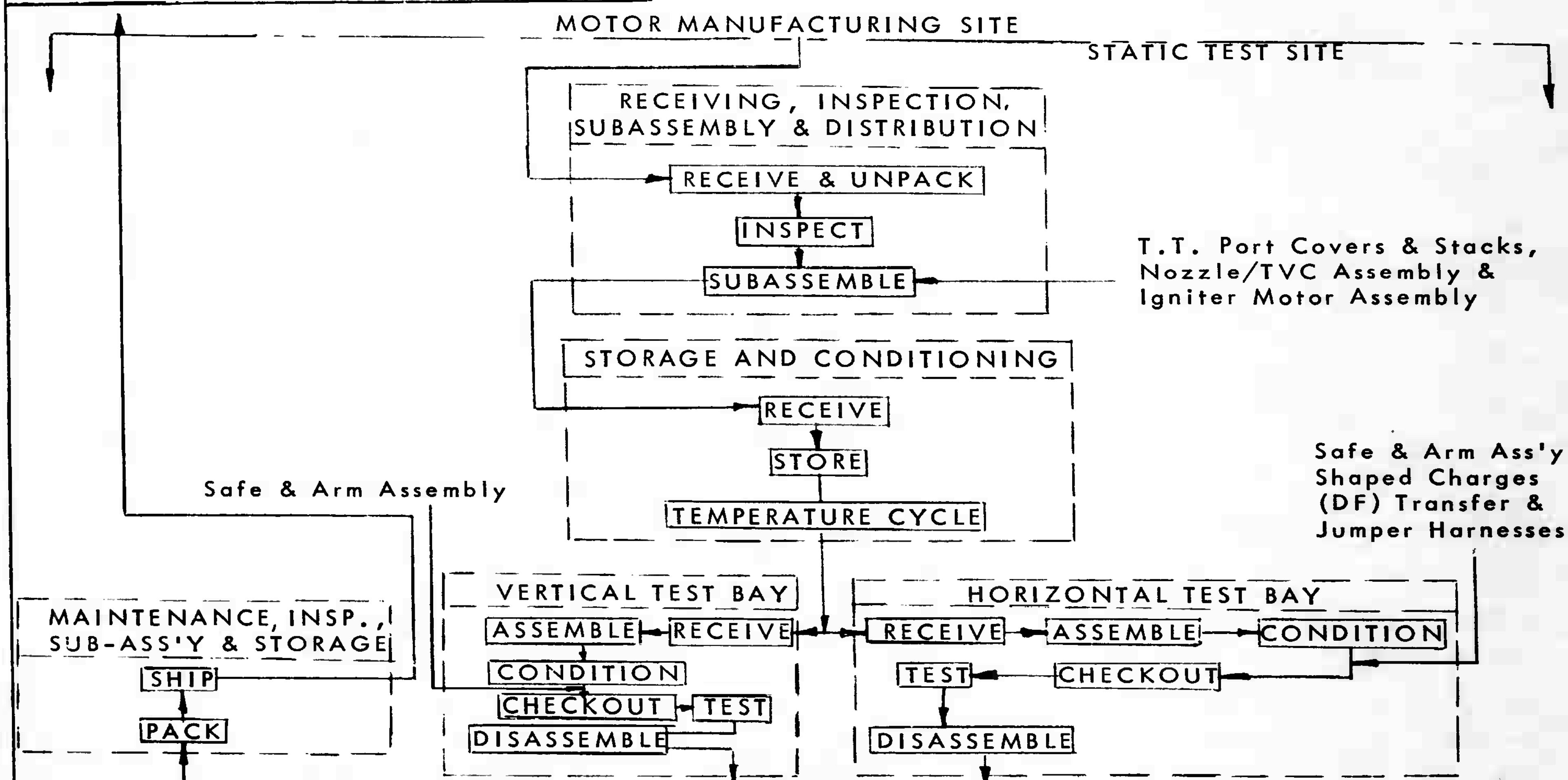


FIGURE 6-32

FUNCTIONAL FLOW CHART FOR 120/156 INCH MOTOR SEGMENTS AND CLOSURES AT THE STATIC TEST SITE

FOR DISCUSSION REFER TO PAGE 6-52

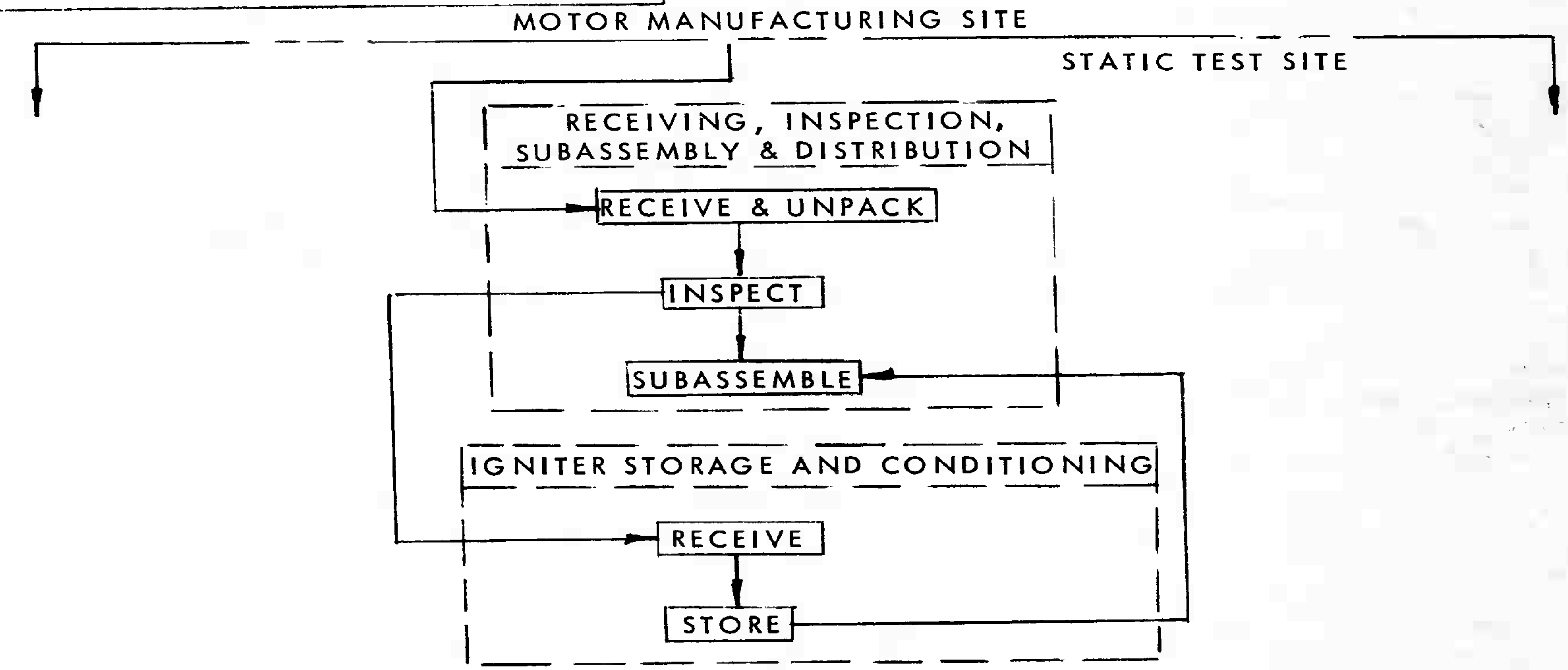


FIGURE 6-33

FUNCTIONAL FLOW CHART FOR 120/156 INCH MOTOR IGNITER MOTOR ASSEMBLY AT THE STATIC TEST SITE

FOR DISCUSSION REFER TO PAGE 6-52

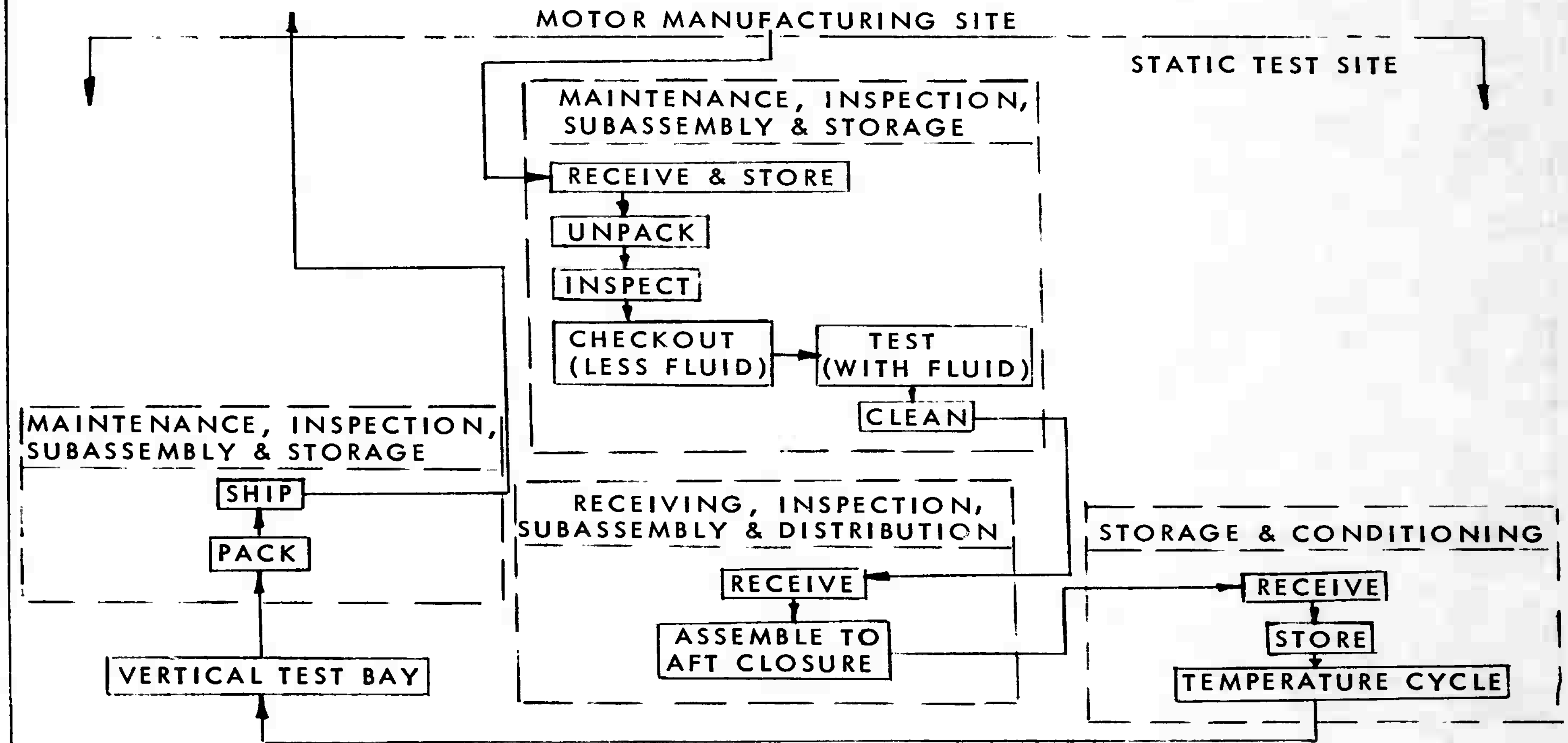


FIGURE 6-34

FUNCTIONAL FLOW CHART FOR 120/156 INCH MOTOR NOZZLE/TVC SUBASSEMBLY AT THE STATIC TEST SITE

FOR DISCUSSION REFER TO PAGE 6-52

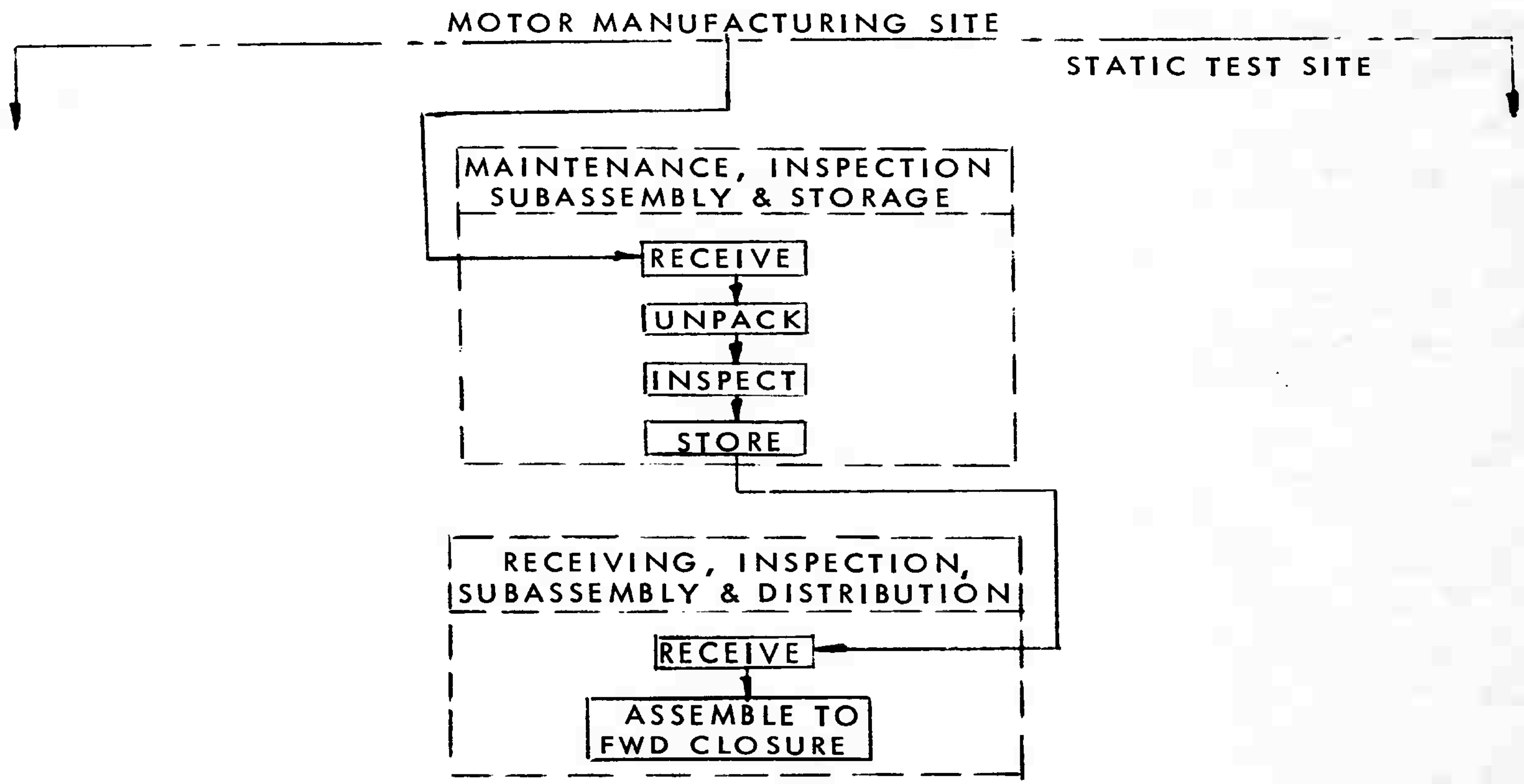


FIGURE 6-35

FUNCTIONAL FLOW CHART FOR 120/156 INCH MOTOR THRUST TERMINATION PORT COVERS AND STACKS AT THE STATIC TEST SITE

FOR DISCUSSION REFER TO PAGE 6-52

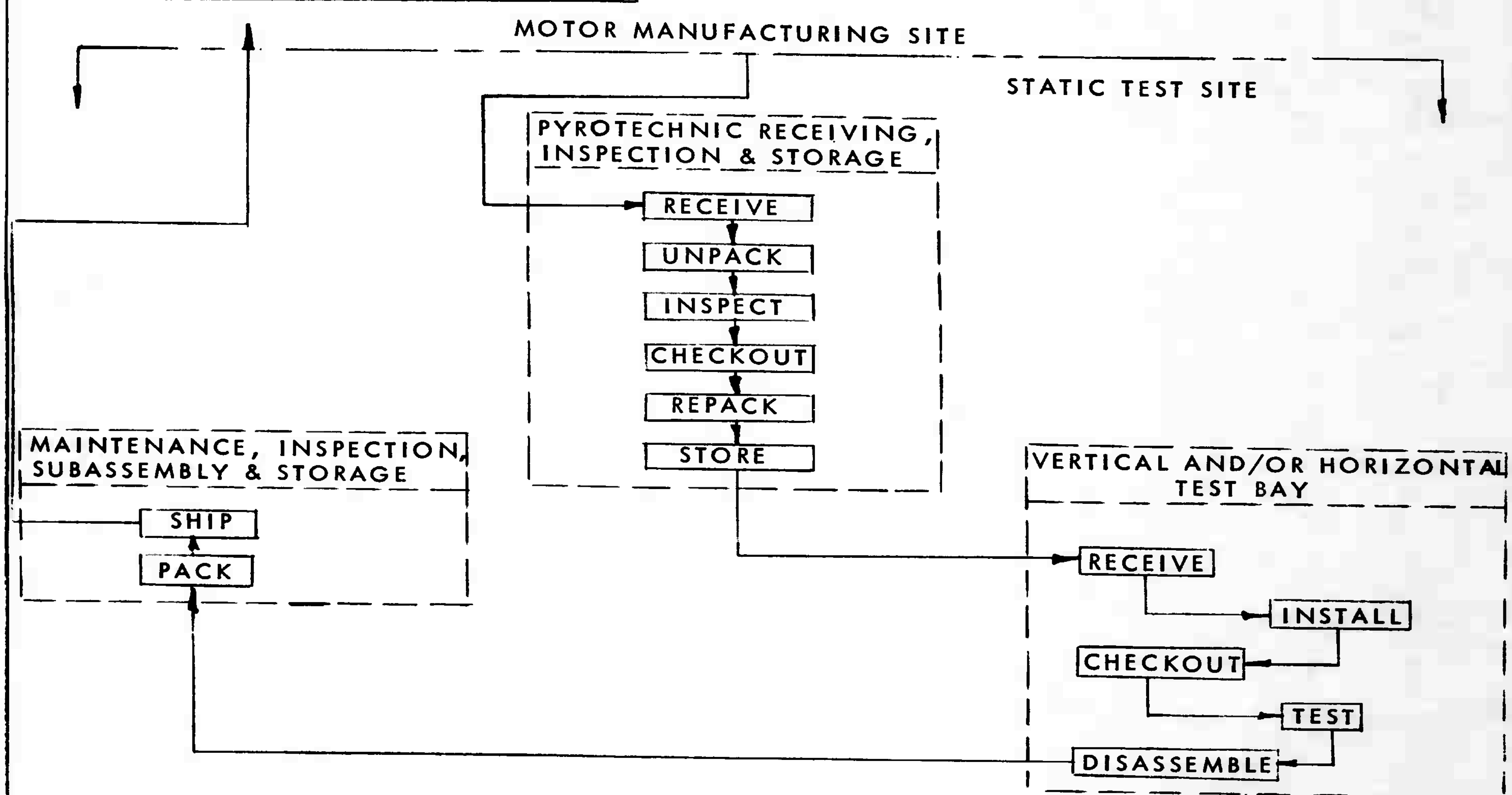


FIGURE 6-36

FUNCTIONAL FLOW CHART FOR 120/156 INCH MOTOR SAFE AND ARMS, SHAPED CHARGES AND DETONATING FUSE TRANSFER AND JUMPER HARNESSES AT THE STATIC TEST SITE

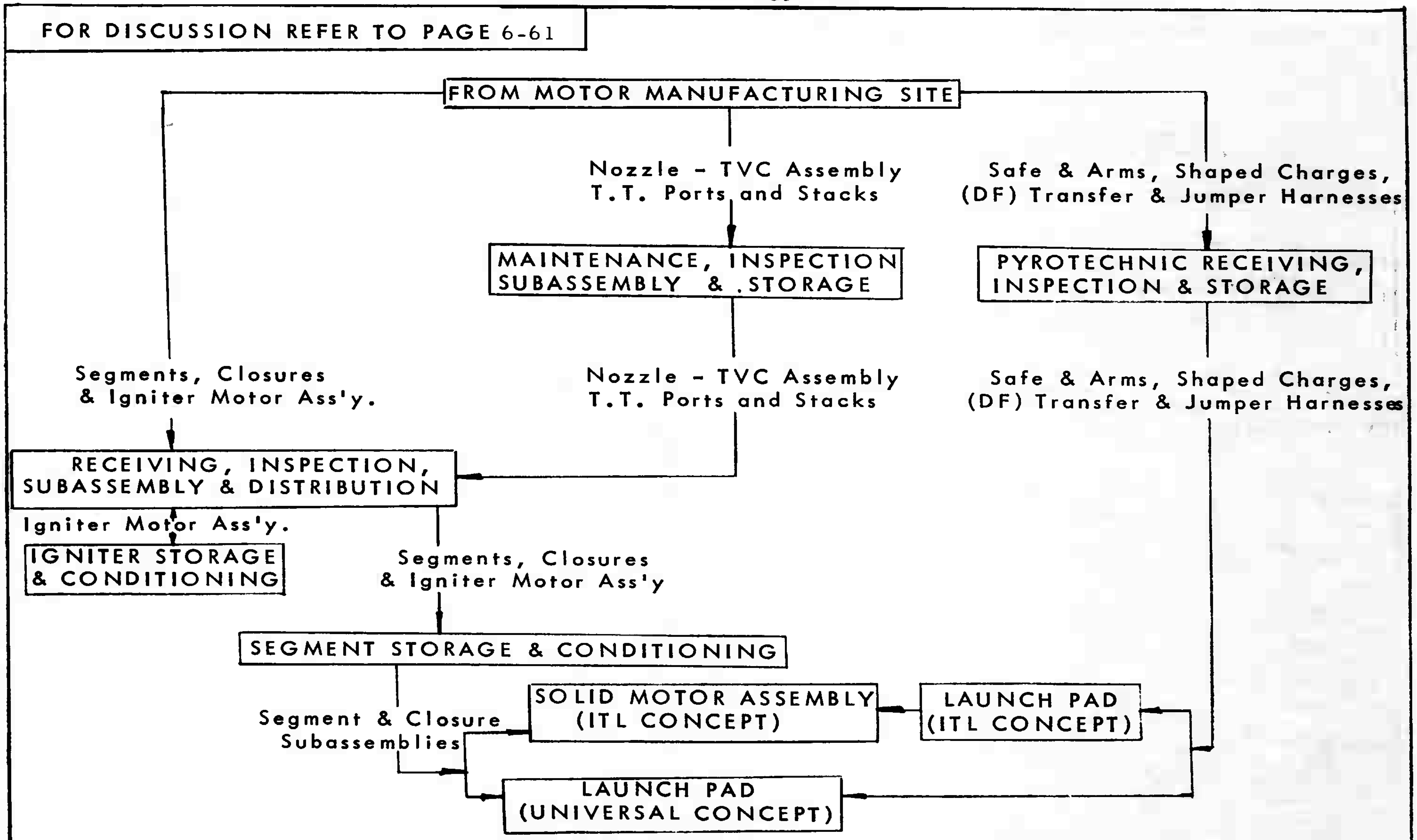


FIGURE 6-37
BASIC FLOW DIAGRAM FOR 120/156 INCH MOTORS AT THE LAUNCH SITE

FOR DISCUSSION REFER TO PAGE 6-61

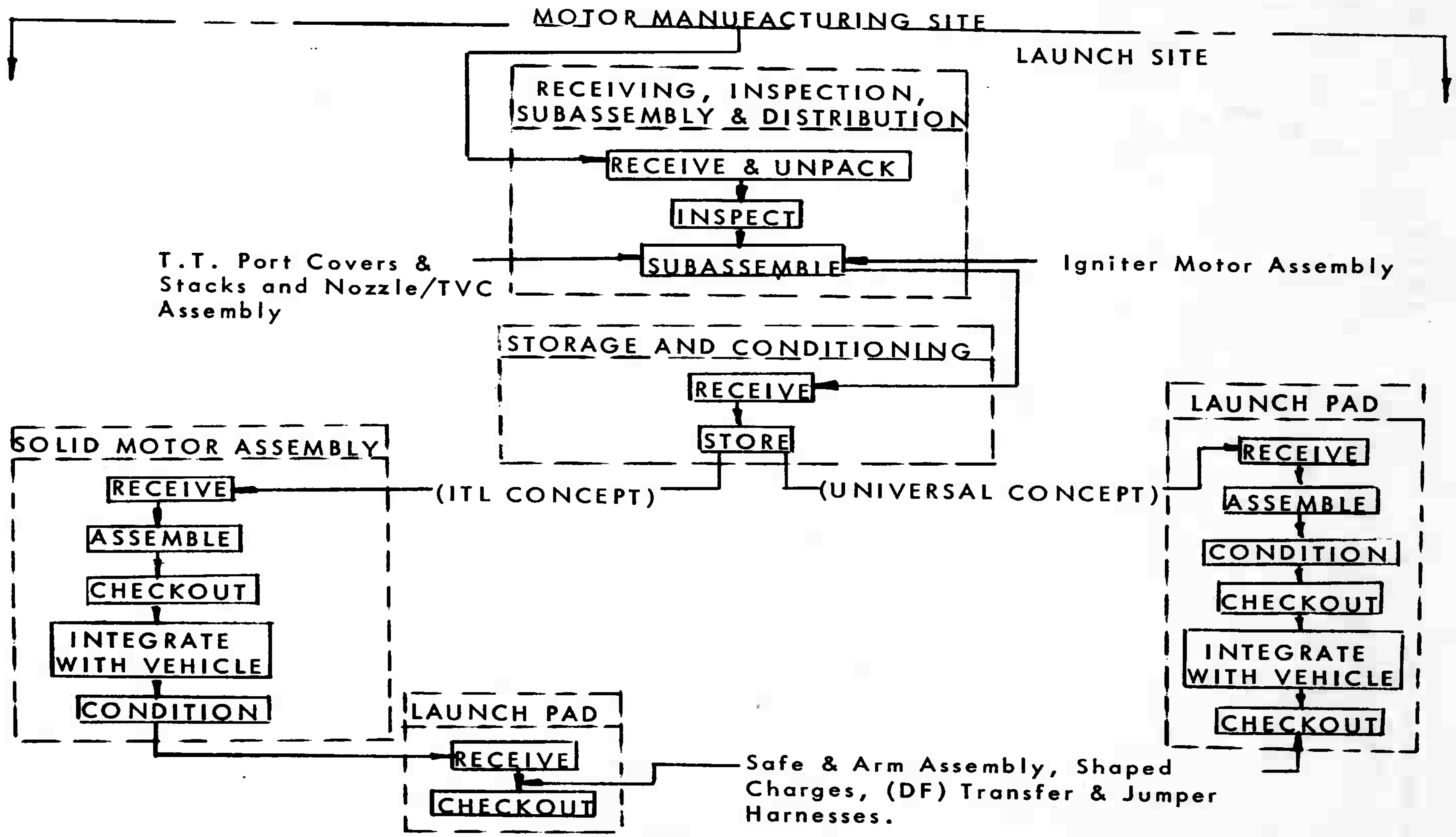


FIGURE 6-38
FUNCTIONAL FLOW CHART FOR 120/156 INCH MOTOR SEGMENTS AND CLOSURES AT THE LAUNCH SITE

FOR DISCUSSION REFER TO PAGE 6-61

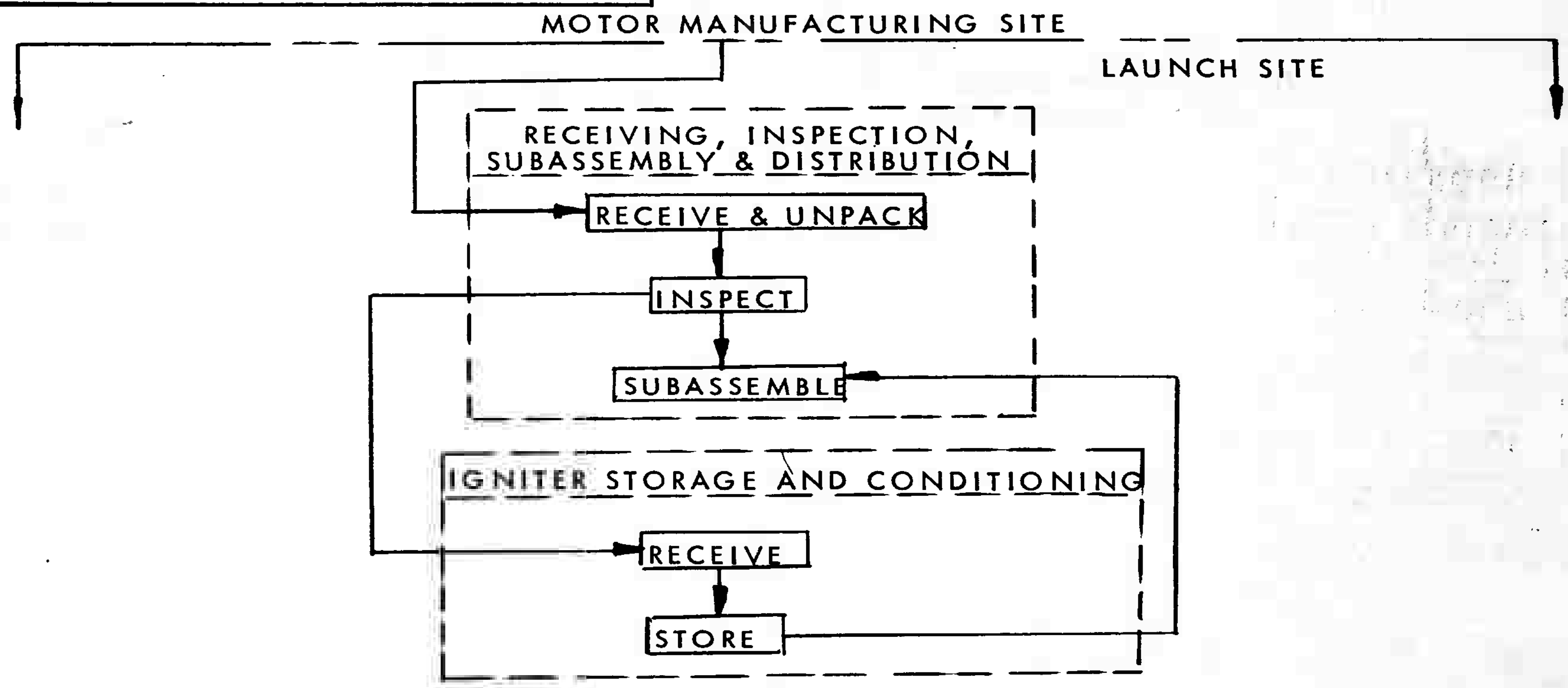


FIGURE 6-39

FUNCTIONAL FLOW CHART FOR 120/156 INCH MOTOR IGNITER MOTOR ASSEMBLY AT THE LAUNCH SITE

FOR DISCUSSION REFER TO PAGE 6-61

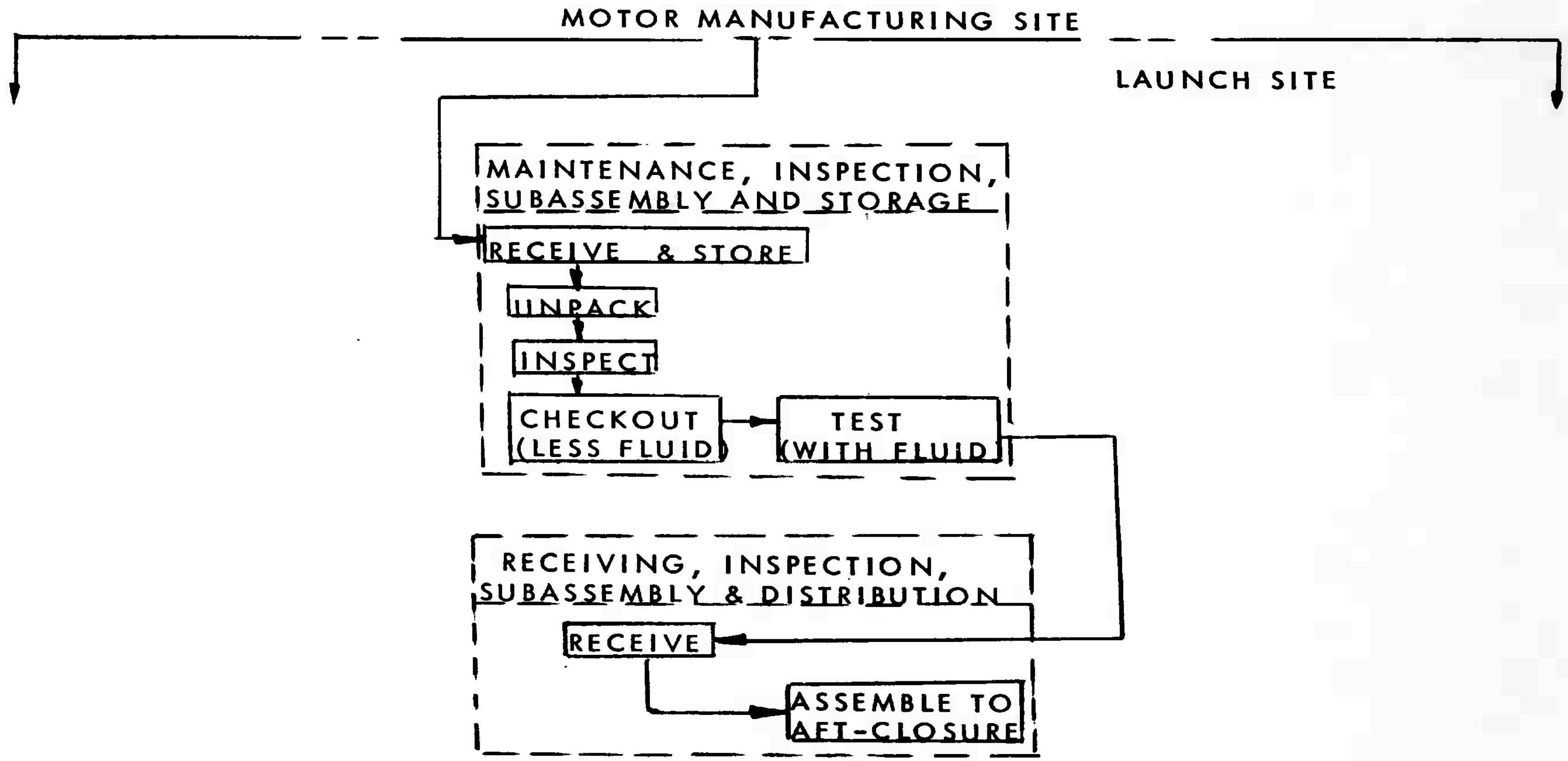


FIGURE 6-40

FUNCTIONAL FLOW CHART FOR 120/156 INCH MOTOR NOZZLE/TVC SUBASSEMBLY AT THE LAUNCH SITE

FOR DISCUSSION REFER TO PAGE 6-61

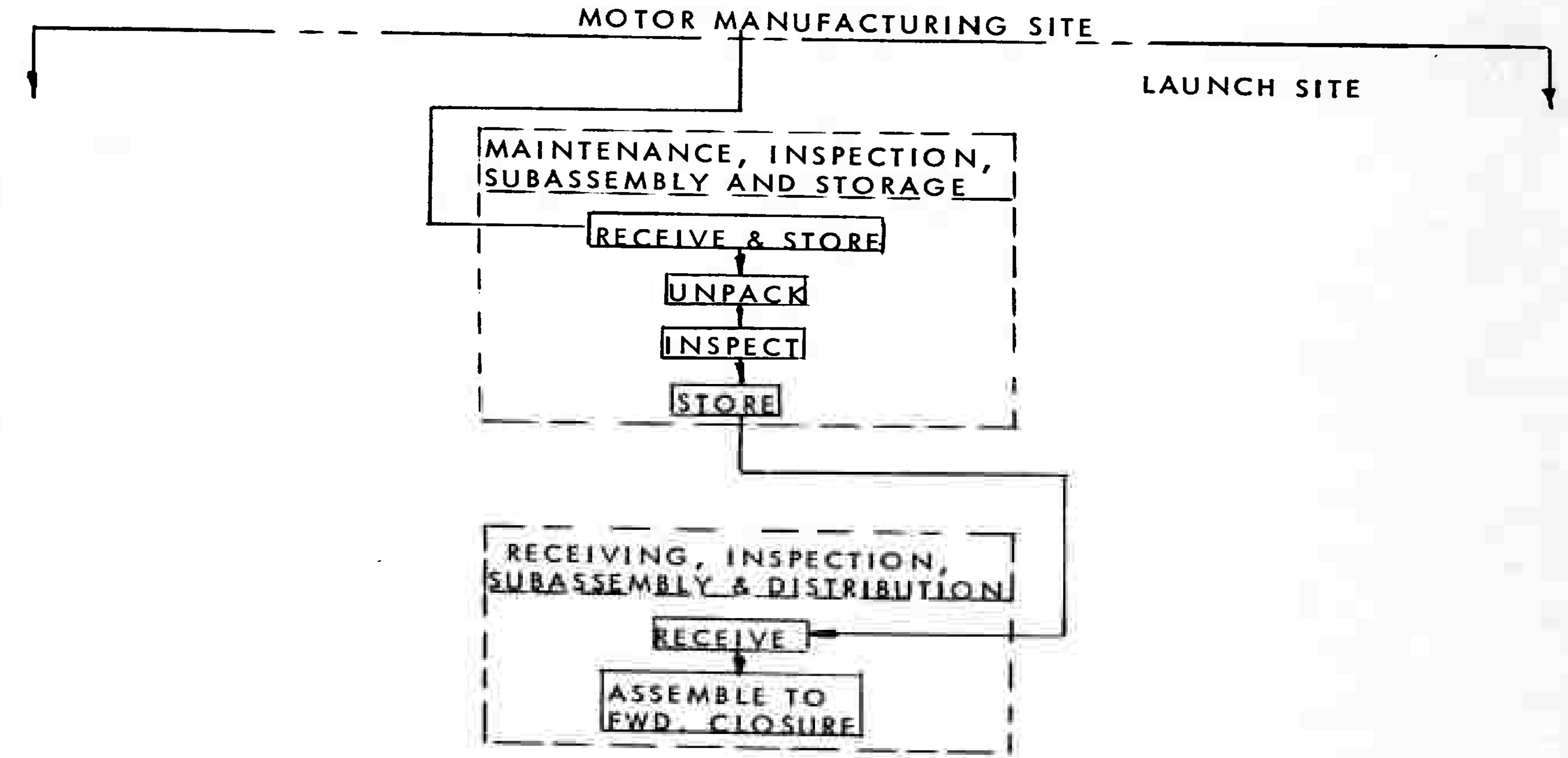


FIGURE 6-41

FUNCTIONAL FLOW CHART FOR 120/156 INCH MOTOR THRUST TERMINATION PORT COVERS AND STACKS AT THE LAUNCH SITE

FOR DISCUSSION REFER TO PAGE 6-61

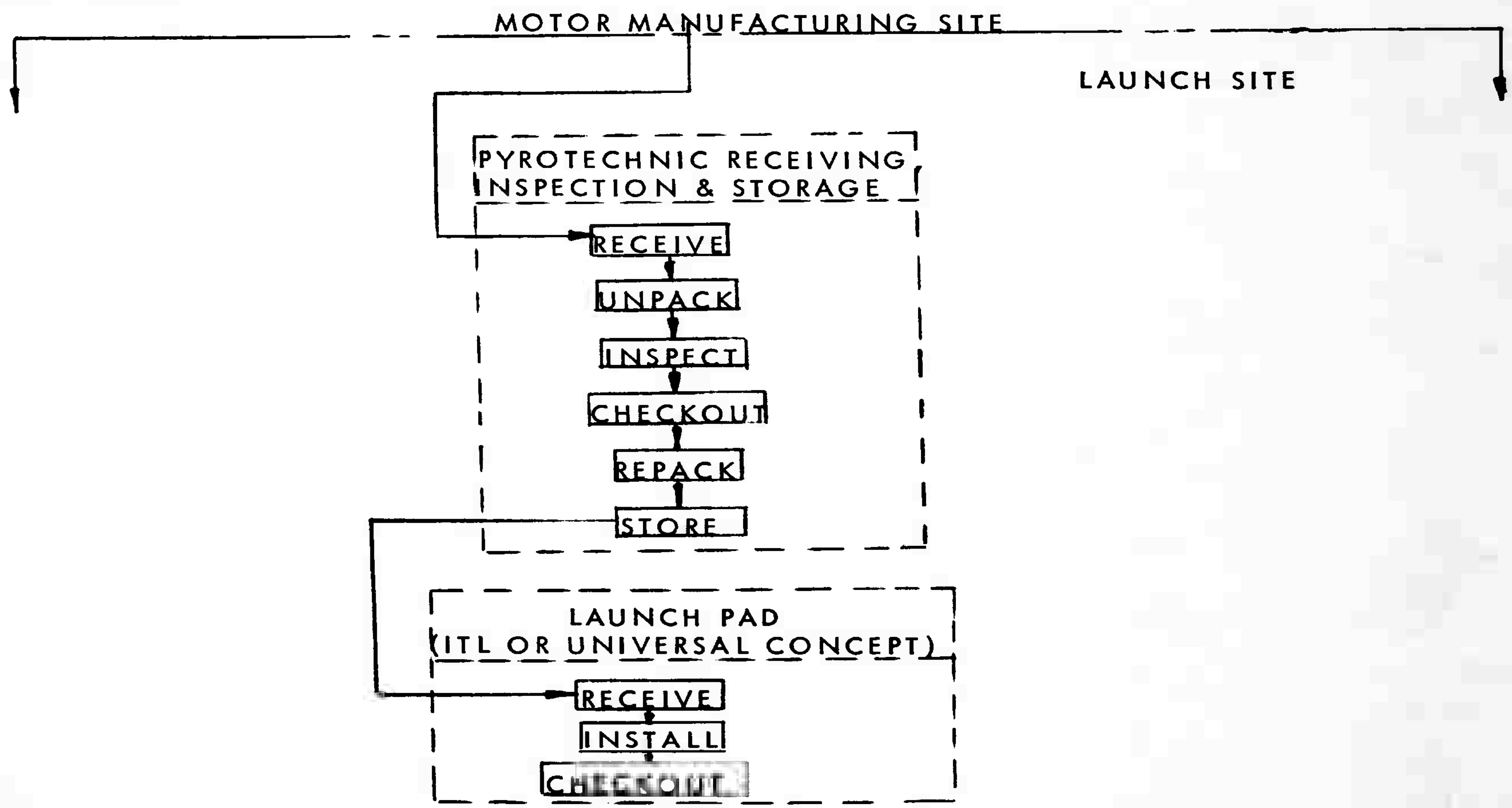


FIGURE 6-42

FUNCTIONAL FLOW CHART FOR 120/156 INCH MOTOR SAFE & ARMS, SHAPED CHARGES AND DETONATING FUSE TRANSFER & JUMPER HARNESSES AT THE LAUNCH SITE

3. TYPICAL AREAS OF ACTIVITY AND RELATED FUNCTIONAL REQUIREMENTS – 260-INCH UNITIZED SOLID PROPELLANT ROCKET MOTOR.

a. General.

This section describes typical functional areas, series of events, and functional requirements for the major unitized motor components at the motor manufacturing site, static test site, and launch site. For each area, preliminary AGE is suggested. (The functional flow charts and diagrams which are referenced in the following paragraphs do not show the flow and accountability of rejected components).

> NOTE: For purpose of clarity operations at the motor manufacturing and static test facilities are being described as if they were two separate facilities. It is pointed out that actually these facilities will be combined. (See Figures 5-21 and 5-30, pages 5-55 and 5-64).

b. Motor Manufacturing Site.

Figure 6-43, page 6-108 is a chart showing the flow of major motor components through the various functional areas (processing stations). These functional areas are defined as follows: receipt of hardware from motor manufacturing vendor, processing, subassembly, preparation for shipment and shipping to either the static test or launch site. Those processing functions (hardware preparation, propellant casting and curing, and casting equipment stripping), which require special tooling will not be discussed in this report since this type of equipment is considered process tooling rather than Aerospace Ground Equipment. Figures 6-44 through 6-48, pages 6-109 through 6-113 illustrate the handling procedures which are performed on each major motor component as it is routed through the various processing stations in the motor manufacturing site.

UNITIZED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
1. INERT HARDWARE RECEIVING, INSPECTION AND DISTRIBUTION. All incoming inert materials are received and inspected in this area. Upon acceptance, they are properly packaged and forwarded to their respective areas for storage or immediate use. The major inert hardware components are the motor case, nozzle and TVC subassembly. NOTE: The following concepts for the manufacturing/static test facility are discussed in Section 5.	Necessary cranes, handling fixtures and dollies to off-load and process the various items of inert hardware (i. e., motor case, nozzle TVC system components, etc.)
a. Submerged Manufacturing/Static Test Facility (Wet Method) (See Figure 5-30, page 5-64.)	For Motor Case: Water Tight Container Winching System For Nozzle: Nozzle Shipping Container and Transport Dolly For TVC Subassembly: Subassembly Shipping Container and Transport Dolly - depending on type of system used. One 20-ton Hoist.
b. Above Ground Manufacturing/Static Test Facility. (Figure 5-21, page 5-55).	For Motor Case: CG Pivot Type Transporter-Erector. Additional equipment as specified above for the wet method.
2. INERT HARDWARE PREPARATION. This facility provides for the general cleaning of motor hardware items, lining and insulation operations, as well as the cleaning and assembly of casting equipment. The cleaning operation includes vapor degreasing, grit blasting, etc. The lining and insulation operations include preparation, application, and curing of liner and insulation to the motor and igniter case hardware.	Necessary cranes, handling fixtures and dollies for processing the various items of inert hardware. Motor Case Handling and Processing will be a major concern in this area - depending on how processing facility is designed.

UNITIZED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
3. PROPELLANT CASTING AND CURING. This facility provides for casting the propellant into prepared motor and igniter case hardware. Upon completion of the propellant casting operation, the motor and igniter propellant grains are allowed to cure under controlled conditions.	Propellant handling is an important factor. The large amount of propellant needed and the pouring technique utilized will establish most of the equipment requirements.
4. CASTING EQUIPMENT STRIPPING AND COMPONENT INSPECTION. After curing of the propellant, casting equipment must be removed and the components inspected, AGE will be required following the removal of the process tooling.	Removal of mandrel and required cure temperatures will dictate equipment requirements.
5. POST CASTING INSPECTION. NOTE: It is assumed that operations 3 and 4 above will be accomplished in the same general area and that the motor case will remain in a vertical attitude throughout.	Radiographic Linac (See Section 10). Ultrasonic Inspection System. Equipment for checking physical dimensions. Weather protection.
After inspection has been completed, the motor is tilted to horizontal position. Following the installation of weather protection, the motor will be moved to motor storage.	A wet pit casting concept (Figure 5-30, page 5-64) requires a watertight shipping container. For a dry concept (Figure 5-21, page 5-55) a motor transporter-erector is required.
6. MOTOR STORAGE AND CONDITIONING. It is not likely that the Manufacturing/Static Test site would be used for motor storage in view of the requirement to vacate it so that the next motor may be started. Storage of the motor could however be accomplished on the motor transporter (barge or caisson) which is used to move the completed motor to the launch facility. Close temperature tolerances should be maintained. The Manufacturing/Static Test Facility must be equipped with close temperature control and temperature cycling capability so that the required static test temperature can be maintained.	With a watertight shipping container, storage could be either on a barge or underwater. Land based storage will require a motor transporter and adequate tie-down (For a motor transporter see Figure 5-21, page 5-55).

UNITIZED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
7. IGNITER SUBASSEMBLY AND INSPECTION.	
a. Igniter Propellant Cartridge. Inspect cartridge, provide weather protection and move to subassembly area or to storage.	Igniter cartridge transport dolly. Weather protection.
b. Igniter Motor Assembly. (1) Receive the igniter motor hardware (case and closure) from inert storage. (2) Install the Propellant cartridge into the Igniter motor case. (3) Assemble the igniter closure to the case. (4) Provide the weather seal for the S&A attach boss and nozzle openings. (5) Move the Igniter motor assembly to the storage area or provide weather protection for movement to the Packaging and Shipping Area. NOTE: The functional areas required for igniters will depend on the type and number of igniters used. It is envisioned that any type of igniter will create similar functional area requirements.	Igniter Motor Transport Dolly. Slings - hoists. Weather Protection.
8. IGNITER STORAGE.	
a. Igniter Propellant Cartridge. Remove weather protection, secure (tie down) cartridge and store until needed for assembly in the igniter motor hardware.	Igniter cartridge transport dolly. Tie-downs. Weather protection.
b. Igniter Motor Assembly. (1) Remove weather protection. (2) Secure (tie down) Igniter Assembly. (3) Store until it is required at either the static test or launch site, then transfer to Packaging and Shipping Area.	Igniter Assembly Transport Dolly. Weather protection.
9. NOZZLE-TVC ASSEMBLY AND INSPECTION.	
a. Nozzle-TVC Subassembly. TVC system components and the motor nozzle are received from the Inert Hardware Receiving, Inspection and Distribution area and assembled to form the Liquid Nozzle-TVC subassembly, TVC pressurization and injectant tankage assembly,	

UNITIZED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
interstage and pressure regulator assembly, and injectant feedline assembly. It appears that the functions required to perform these assembly operations will not require special AGE other than previously discussed.	
NOTE: The functional areas required for the TVC system will depend on the type of system used. However, any TVC system will create similar functional areas and requirements (See Paragraph (b) , page 6-5 for additional discussion).	
(1) Check out the nozzle-TVC subassembly (without fluid) to verify its performance.	Checkout Equipment (not included in this effort).
(2) Install weather protection for interplant handling.	Weather protection.
(3) Move the subassembly to the TVC Functional Cold Flow Test Area.	Transport dolly and special support structure.
b. Tankage and Pressure Regulator Assembly.	
(1) Assemble the pressurization tank, interstage and pressure regulator components, injectant tanks and forward section of the injectant feed line into a unit.	TVC Assembly Fixture. TVC Handling Dolly.
(2) Conduct leak test and functional checkout (without fluid) on the pressure regulator assembly.	20-ton Overhead Crane. Checkout Equipment (not included in this effort).
(3) Provide weather protection for in-plant handling and move the assembly to the TVC functional checkout area.	Weather protection.
10. NOZZLE TVC FUNCTIONAL CHECKOUT.	
a. General.	
This area has the capability for full functional checkout of the Nozzle-TVC System before shipment to either the static test or launch site.	
(1) Remove the weather protection for in-plant handling and install the nozzle-TVC system in the test bay.	Weather Protection.
(2) Fill and charge the fluid and pressurization tanks.	Transport Dolly and special support structure.
(3) Conduct cold flow tests.	20-ton Hoist.
(4) Clean and purge the system and disconnect it from test bay.	Checkout Equipment (not included in this effort).

UNITIZED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
(5) Reinstall weather protection for in-plant handling and move the assembly either to storage or to Packaging and Shipping Area.	
11. NOZZLE - TVC STORAGE PACKING AND SHIPPING.	
a. General. The Nozzle-TVC assembly is stored, packaged and prepared for shipment in this building. The following operations are performed:	
(1) Remove in-plant weather protection and store the assembly.	Special Nozzle/TVC Shipping Container.
(2) Install necessary instrumentation and package the assembly for shipment to either the static test or launch site.	For additional equipment, see Paragraph 9a, pages 6-92 and 6-93.
12. PYROTECHNIC SYSTEMS RECEIVING INSPECTION AND SHIPPING.	
a. General. Pyrotechnics are received, inspected, checked out, and prepared for shipment in this building.	
b. Safe and Arm Assembly. The Safe and Arm Assembly is unpacked, inspected and checked out in this area.	Special Packaging.
c. Shaped Charges and Detonating Fuse Transfer and Jumper Harnesses.	
(1) Unpackage and inspect the assembly.	
(2) Repackage the assembly and move it to the Pyrotechnic Storage Area for storage.	
13. PYROTECHNIC SYSTEMS STORAGE. This building provides conditioned storage for the pyrotechnic assemblies.	
14. PACKAGING AND SHIPPING. Components containing propellants are packaged and prepared for shipping in this area.	
a. Receiving and Inspection from Storage.	
(1) Remove in-plant weather protection from the motor.	Weather protection.
(2) Visually inspect the components prior to packaging.	

UNITIZED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
b. Packaging. (1) Install necessary instrumentation and package the components for shipment to either the static test or launch site.	
c. On-Loading to Prime Transporter. Long line transport of the 260-inch unitized motor will be accomplished via water. For a detailed discussion of water transportation and equipment, see Section 9.	A wet handling technique will require a watertight shipping container similar to the one in Figure 5-30, page 5-69. A dry handling concept will require a motor transporter similar to the one in Figure 5-21, page 5-55.

c. Static Test Site.

Figure 6-49, page 6-114 shows major motor component flow and function areas for receipt of components from the motor processing site through assembly, checkout and test. Figures 6-50 through 6-54, pages 6-115 through 6-119 describe the requirements of each functional area for major motor components at the Static Test Site. The following functional analysis is applicable to both vertical and horizontal static testing, with the exception of thrust vector control (vertical test only), and thrust termination and destruct (horizontal test only). These exceptions are noted in the following discussion.

> NOTE: For the purpose of clarity, operations at the Motor Manufacturing and Static Test Facilities are described as if they were two separate facilities. It is pointed out that these facilities will be combined (see Figures 5-21 and 5-30, pages 5-55 and 5-64).

UNITIZED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
1. RECEIVING, INSPECTION, SUBASSEMBLY AND DISTRIBUTION.	
NOTE: Since the motor would be poured in this area, receiving and inspection operations apply primarily to inert motor hardware i. e., motor case, nozzle and TVC subassembly. This procedure has been covered under Motor Manufacturing (refer to Paragraph 1, page 6-90 of this section). Additional receiving and inspection operations would be performed on the igniter motor as described below.	
a. Igniter Motor Assembly. (1) Unpackage the assembly and move it to the inspection area. (2) Remove the igniter closure and perform inspection. (3) Reassemble and move the assembly to Igniter Storage and Conditioning Area.	Igniter motor transport dolly. Hoist slings. Weather protection.

UNITIZED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
2. MOTOR STORAGE AND CONDITIONING. It is not likely that the Manufacturing/Static test site would require a motor storage area since static test would normally be accomplished in the casting pit after completion of the manufacturing cycle. If desired, storage could be accomplished on the motor transporter which is used to move the completed motor to the launch facility. Close temperature tolerances (plus or minus 5 degrees) would have to be maintained). The Manufacturing/Static Test Facility must be equipped with close temperature control and temperature cycling capability so that the required static test temperature can be obtained.	
3. IGNITER STORAGE & CONDITIONING. This facility provides conditioned storage for the igniter motor assembly. Temperature cycling of these components (if required) may be accomplished in this area. (1) Receive igniter motor assembly from the Receiving, Inspection, Subassembly and Distribution Area. (2) Remove weather protection, secure (tie-down) and ground the components in storage. (3) Store the components at required temperature until they are needed for subassembly to the forward end of the motor.	
4. PYROTECHNIC RECEIVING,,INSPECTION & STORAGE. a. Safe and Arm Assemblies.	
(1) Receive assemblies from the motor manufacturing site and unpackage.	Special Packaging.
(2) Inspect and check out the assembly. (3) Repackage the assemblies and move them to the Pyrotechnic Storage Area. (4) When needed, move the igniter safe and arm assembly only to the vertical test bay.	

UNITIZED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
b. Shaped Charges and Detonating Fuse Transfer and Jumper Harnesses (for Horizontal Test Only).	
(1) Receive components from the motor manufacturing site and unpackage. Inspect, repackage and move them to Pyrotechnic Storage.	Special Packaging.
(2) When needed, move the thrust termination and destruct system to the horizontal test bay.	
5. MAINTENANCE, INSPECTION, SUBASSEMBLY & STORAGE.	
All inert parts and components are received from the motor manufacturing site, unpackaged, inspected, and stored in this building until needed. The nozzle-TVC assembly which was previously assembled at the Nozzle/TVC Assembly and Inspection Area of the motor processing site is checked out, cold-flow tested, and stored as an assembly in this building. The TVC system is a major subassembly requiring a functional checkout in this area. The basic requirements for this system are discussed below.	
a. Nozzle-Liquid TVC Subassembly. (TVC Tankage, Pressurization Tank, Interstage and Pressure Regulator Assembly, Injectant Launcher Assembly and Injectant Feedline).	
(1) Receive components from the motor manufacturing site and unpackage them.	Weather Protection.
(2) Inspect and assemble the tankage components together and perform a leak test on the tankage assembly. (3) Checkout (without injectant fluid). (4) Provide weather protection and move the assembly to the cold flow test bay. (5) Remove weather protection then assemble and install the components (in the flight attitude) into the test bay. (6) Fill and charge the fluid pressurization tanks. (7) Conduct the cold flow test and check out the system.	The cold flow test will require provision of an inert compatible gas or liquid to determine functional capability of the system. Valve responses and flow leaks will be a major concern. Gimble or jet tab TVC systems would require a measuring device to determine the degree of gimbling or tab movement.
(8) Monitor in accordance with checkout requirements outlined under "Ground Instrumentation Requirements", Figure 6-24, page 6-43.	

UNITIZED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
(9) Following the cold flow functional test, clean and purge the system and disconnect it from the test bay.	
(10) Provide weather protection and move the components back to the storage area until they are needed for assembly to the motor.	
b. Aft Skirt Extension, Exit Cone Extension and TVC Subassemblies (TVC Tankage, Nose Cone, Support Skirt and Bracket and Motor Attach Bracket Assemblies).	
(1) Receive components from the motor manufacturing site and unpackage them.	10-ton Crane. Weather protection.
(2) Inspect and check out.	
(3) Provide weather protection and move the components to the appropriate test bay.	
6. STATIC TEST.	
a. Vertical Test Bay. This facility provides for assembly, servicing, checkout, conditioning and test of the complete rocket motor in the inverted position with nozzle up. (Destruct and thrust termination tests will not be accomplished at this facility).	
(1) Motor Assembly and Static Checkout.	25-ton Crane.
(a) Tilt motor to the vertical (nozzle up) attitude and install and secure it to the test bay.	Nozzle & TVC transport dollies.
(b) Assemble the aft skirt extension to the aft stub skirt, TVC tankage components to the motor, and nozzle TVC subassembly to the aft end of the motor.	Dry handling technique will require a motor erector (see Figure 5-21, page 5-55).
(c) Connect the Injectant Feed Line to the tankage nozzle manifold, and assemble the nozzle exit cone extension to the nozzle.	A wet handling technique will use a floatation method to erect the motor. It will also require a sealed container (see Figure 5-30, page 5-64).
(d) Fill and charge the TVC fluid and pressurization tanks.	Propellant handling equipment for liquid injection.
(e) Provide environmental protection and install the Safe and Arm Assembly to the igniter motor.	Purging and decontamination equipment for toxic propellants.
(f) Install the final instrumentation, conduct final checkout and static test.	Test equipment (not included in this effort).

UNITIZED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
(2) Test. To provide for a satisfactory evaluation of motor performance throughout development and flight tests, there will be requirements to monitor, record, and evaluate certain motor parameters. Figure 6-24, page 6-43 indicates the parameters applicable to static testing of the assembled rocket motor.	
(3) Disassembly. Disassembly of the motor follows a procedure which is the reverse of Paragraphs 6 a (1) and 6 a (2), pages 6-99 and 6-100.	Disassembly equipment. NOTE: For additional equipment, refer to Paragraph 6-a, page 6-99.
(4) Distribution of Parts to Maintenance Facility. Return the disassembled motor components to the Maintenance, Inspection and Subassembly area for packaging and return shipment to the motor manufacturing facility.	Component Transport Dollies. Weather Protection.
b. Horizontal Test Bay. This facility provides for assembly, servicing, checkout, conditioning and test of a complete rocket motor in the horizontal position. It appears that any preliminary destruct or thrust termination test would be conducted in this attitude. TVC data would be compromised but could be calculated. NOTE: The concept of horizontal testing is a function of the configuration of the Manufacturing/Static Test Facility. It is possible to destruct test in the vertical position if precautions are taken. The sequence of motor assembly, with the exception of thrust vector control system servicing and checkout, is as follows:	
(1) Motor Assembly and Static Checkout. (a) Assemble the aft skirt extension to the aft stub skirt. (b) Install and secure the motor in the test bay, install the nozzle and nozzle exit cone extension. (c) Provide environmental protection. (d) Install the Safe and Arm Assembly into igniter motor. (e) Assemble the destruct system safe and arm assembly in its place on the forward end of the motor.	Since this test would be rare and would likely be accomplished in a remote area with a minimum of facility installation, no equipment is specified.

UNITIZED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
(f) Attach shaped charges onto the motor case. (g) Connect the jumper harness between the shaped charges. (h) Attach the transfer harness to the Safe and Arm Assembly. (i) Provide instrumentation and conduct final checkout. (j) Perform static test. (2) Test. To provide for a satisfactory evaluation of motor performance throughout development and flight tests, there will be requirements to monitor, record, and evaluate certain motor parameters. Figure 6-24, page 6-93 indicates those parameters applicable to static testing of the assembled rocket motor. (3) Disassembly. Disassembly of the motor follows a procedure which is the reverse of Paragraph 6 b, above.	
(4) Distribution of Parts to Maintenance Facility. Return disassembled motor components to Maintenance, Inspection and Subassembly area for packaging and return shipment to the motor manufacturing facility.	See equipment listed under 260-inch motor manufacturing facility, page 6-90.

d. Launch Site.

Figure 6-55, page 6-120 shows the major motor component flow and functional areas from receipt of components from the motor manufacturing site through assembly and checkout at the launch pad.

Figures 6-56 through 6-59, pages 6-121 through 6-124 describe the requirements at each functional area for the major motor components.

Two final vehicle assembly concepts are considered as follows:

1) The Universal Pad Concept. (All assembly operations are performed on the launch pad).

2) The Integrated Transfer and Launch Concept. (All assembly operations are performed off the launch pad. Mating of solid and liquid stages occurs at an intermediate mating station then the complete vehicle is transported to the launch pad. The functional analysis presented below is applicable to both concepts to the point of final assembly of the vehicle). (Paragraph 6-Motor and Vehicle Assembly).

NOTE: The discussion of the 260-inch unitized motor supplied below is predicated on a general concept which assumes receipt of the motor via long line transporter at the launch site, and horizontal transportation of the motor. Eventual clustering at either the launch pad or the intermediate mating station by means of a crane is also assumed. It should be pointed out that many other schemes are possible (refer to Section 11) and that optimization of concepts would require a detailed study of launch rate, number of motors required to form a booster, and various erection and transportation schemes.

UNITIZED MOTOR FUNCTIONAL REQUIRMENTS	SUGGESTED EQUIPMENT
1. RECEIVING, INSPECTION, SUBASSEMBLY AND DISTRIBUTION.	
a. Motor. Upon arrival on the long line transporter, the motor is removed by a handling and transport device and moved to an inspection area. This equipment must be provided with environmental conditioning. The following is then accomplished: (1) Remove long distance weather protection and inspect. (2) Install igniter motor and any necessary instrumentation. (3) Install intersite weather protection for movement to either storage or launch pad.	A water handling method would require a shipping container. The motors might be stored on a barge. A dry scheme requires a motor transporter and weather protection.
b. Igniter Motor Assembly. (1) Unpackage the assembly and move it to the inspection area. (2) Remove the igniter closure and perform necessary inspection. (3) Reassemble the unit and move the assembly to the subassembly area for installation into the forward closure.	Igniter transport dolly. Igniter insertion fixture hoist slings.
2. MOTOR STOAGE AND CONDITIONING. NOTE: The storage requirements for the 260-inch motor have not been defined. It is conceivable that long term storage (several years) may be necessary. Storage may be within buildings, or in the open with the proper environmental protection provided. Proposals have been made for long term underwater storage. The procedure described below is predicated on the existance of a storage building. This facility provides conditioned storage for the 260-inch unitized motor.	
(1) Receive the subassembly from the Receiving, Inspection, Subassembly and Distribution Area. (2) Remove weather protection and secure (tie down) and ground the motor. (3) Store the motor at the required temperature until it is needed at either the Solid Assembly Building or Launch Pad, at which time weather protection will be provided.	Weather protection. A dry handling concept would require a Motor Transporter and tie-downs. A wet handling method would require a shipping container.

UNITIZED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
3. <u>IGNITER STORAGE AND CONDITIONING AREA.</u>	
This facility provides conditioned storage for the igniter motor assembly. (1) Receive igniter motor assembly from the Receiving, Inspection, Subassembly and Distribution Area. (2) Remove weather protection, secure (tie-down) and ground the components in storage. (3) Store the components at required temperature until they are needed for subassembly to forward end of the motor. (4) Reassemble the weather protection and return the components to Receiving Inspection, Subassembly and Distribution Area.	Igniter motor transport dollies. Weather protection. Tie-downs.
4. <u>PYROTECHNIC RECEIVING, INSPECTION AND STORAGE.</u>	Special Packaging.
a. <u>Safe and Arm Assemblies.</u> (1) Receive assemblies from the motor manufacturing site and unpackage. (2) Inspect and check out the assemblies. (3) Repackage the assemblies and move them to the storage area. (4) When needed, move the igniter safe and arm assembly to the launch pad of Solid Motor Assembly Building.	
b. <u>Shaped Charges and Detonating Fuse Transfer and Jumper Harnesses (for Horizontal Test Only).</u>	
(1) Receive components from the motor manufacturing site and unpackage. (2) Inspect, replackage and move them to Pyrotechnic Storage. (3) When needed, move the thrust termination and destruct system to the horizontal test bay.	Special Packaging.
5. <u>MAINTENANCE, INSPECTION, SUBASSEMBLY AND STORAGE.</u>	
All inert parts and components are received from the motor manufacturing site, unpackaged, inspected and stored in this building until needed. The nozzle-TVC	

UNITIZED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
assembly which was previously assembled at the Nozzle/TVC Assembly and Inspection Area of the motor processing site is checked out, cold-flow tested, and stored as an assembly in this building. The TVC system is a major subassembly requiring a functional checkout in this area.	
a. <u>Nozzle-Liquid TVC Subassembly. (TVC Tankage, Pressurization Tank, Interstage and Pressure Regulator Assembly, Injector Subassembly and Injectant Feed Line).</u> (1) Receive components from motor manufacturing site and unpackage them. (2) Inspect and assemble the tankage components and perform leak test on the tankage assembly. (3) Check out (without injectant fluid). (4) Provide weather protection and move to cold flow test bay. (5) Remove weather protection then assemble and install the components (in the flight attitude) into test bay. (6) Fill and charge the fluid pressurization tanks. (7) Conduct the cold flow test and check out the system. (8) Monitor in accordance with checkout requirements outlined under "Ground Instrumentation Requirements", Figure 6-24, page 6-43. (9) Following cold flow functional test, clean and purge system and disconnect it from the test bay. (10) Provide weather protection and move the components back to the storage area until they are needed for subassembly to the motor.	Pressure source. Leak detector. Test equipment (not included in this study). Transport dolly and special support structure. 25-ton Crane. Weather Protection. NOTE: The cold flow test will consist of using an inert compatible gas or liquid to determine functional capability of the system. Valve responses and flow leaks will be a major concern. Gimble or jet tab TVC systems would require a measuring device to determine the degree of gimbling or tab movement.
b. <u>Aft Skirt Extension, Exit Cone Extension and TVC Subassemblies (TVC Tankage, Nose Cone, Support Skirt and Bracket and Motor Attach Bracket Assemblies).</u> (1) Receive components from the motor manufacturing site and unpackage them. (2) Inspect and check out. (3) Provide weather protection and move the components to the launch pad or Solid Motor Assembly Building.	10-ton Crane. Weather Protection.

UNITIZED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
6. MOTOR AND VEHICLE ASSEMBLY.	
a. Integrated Transfer and Launch Techniques. NOTE: The off-pad assembly concept corresponds to the Integrated Transfer and Launch Technique concept projected for the segmented motors. Because of the great height and complexity of vehicles utilizing clustered 260-inch monolithic motors for the booster stage, completely integrated behicles will complicate completed vehicle transport for the ITL concept. In this technique, clustering of the boosters would be accomplished off the pad prior to moving them to the pad via a booster transporter. Upper stages would come to the pad as integrated units to be mated to the booster (see Figures 5-42 and 5-43, pages 5-25 and 5-76). For an additional discussion of the off pad assembly technique envisioned for the large monolithic motors, refer to Section 5. The discussion of the ITL technique for the monolithic motor will assume that the motors are ready to be assembled into boosters. Inspection and subassembly operations, following long term storage, would be identical to those discussed above in Paragraph 1, page 6- 90 .	
(1) Motor and Booster Assembly Area. (a) Monolithic motors would be broght to this area assembled, erected and clustered onto a Vertical Booster transporter. (b) The TVC system would be assembled to the clustered booster. This could be done before or after erection of the solid motors, depending upon the TVC concept and the erection concept used.	Erection and Clustering Equipment could be a Gantry or a CG pivot type erection. mechanism. See Figures 5-34B and 5-40, pages 5-68 and 5-73 also refer to Section 5.
(c) Following completion of the booster assembly, the Vertical Booster Transporter is brought to the launch pad.	Vertical Booster Transporter. Booster transporters may employ rubber tires, rail wheels, crawlers or barge/canal modes.
(2) Launch Pad Operations. At the launch pad, the Vertical Booster Transporter becomes the launch platform. The transporter wheels or crawlers (depending on	Individual motors weight approximately 3. 5 million pounds. Clustered boosters

UNITIZED MOTOR FUNCTIONAL REQUIREMENTS	SUGGESTED EQUIPMENT
concept) are removed and the platform tied to the pad. In the case of barge/canal transportation of the booster, the entire barge would be ballasted and sunk onto a prepared foundation. The upper stages would then be brought in as described above. Once the Vehicle is assembled, checkout operations can be conducted and the vehicle made ready for launch.	of 4 or more (up to 7) are envisioned.
b. <u>Universal Launch Pad Technique.</u> The discussion of the Universal Pad technique will assume that the motors are ready to be assembled into boosters. Inspection and subassembly operations, following long term storage would be identical to those discussed above in Paragraph 1, page 6-90 . A number of erection and clustering concepts are discussed in Sections 5 and 11.	For equipment concepts and discussion, refer to Figures 5-35 through 5-39, pages 5-69 through 5-79 and Section 11.
Motors can be erected at an intermediate erection station and then brought to the pad via vertical transporter or moveable gantry; or they may be erected and clustered at the pad. The TVC system (depending on its configuration) may be assembled to the individual motors prior to erection, or it may be assembled to the clustered booster.	Equipment similar to that described in Paragraph 6,a, page 6-93.
Assembly of upper stages would depend upon the concept used. It is conceivable that they would be assembled by gantry or, if desired, they could be brought in as an integrated unit. Once the vehicle is assembled, checkout operations are conducted. The vehicle is now ready for launch.	Environmental protection. Assembly and Disassembly Equipment.

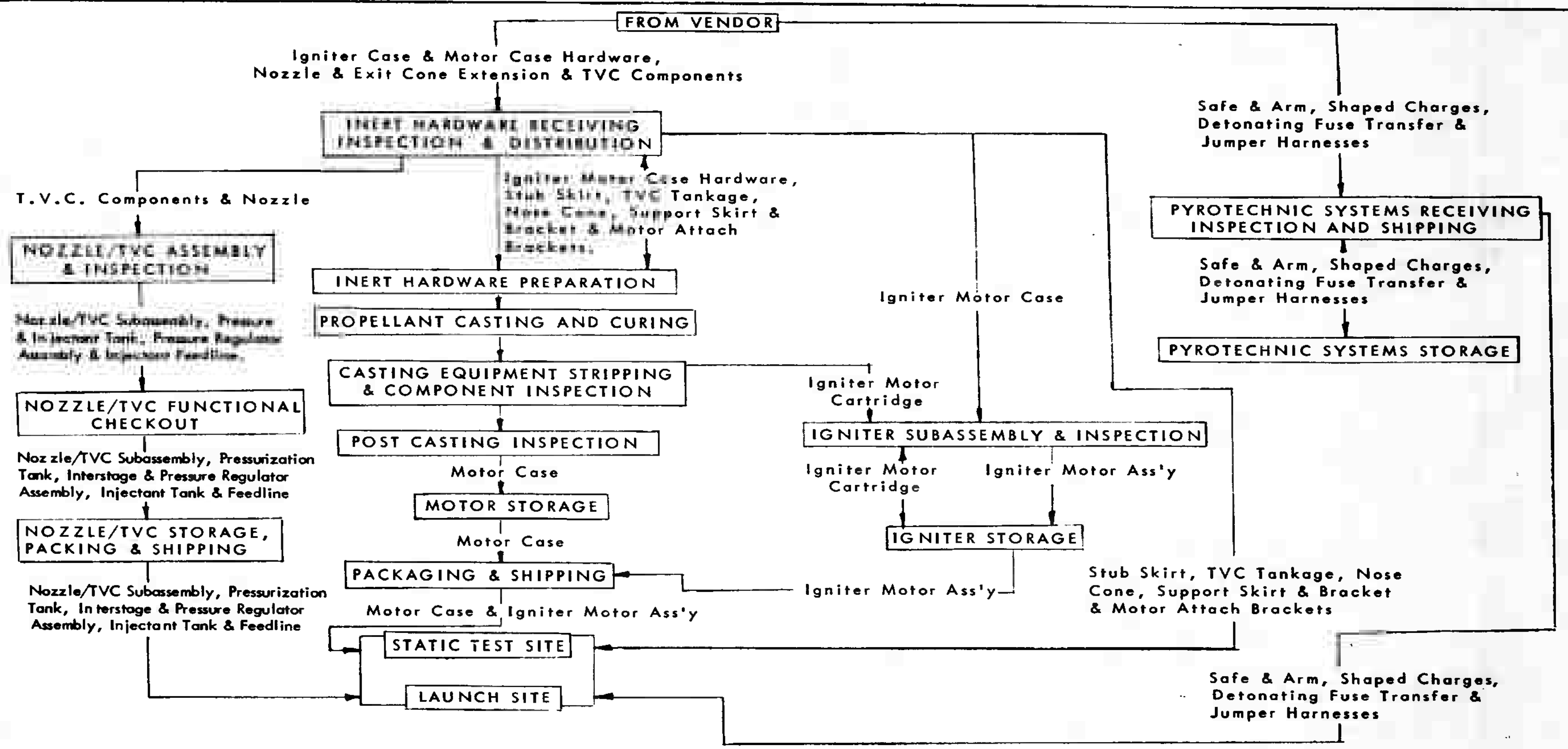


FIGURE 6-43
BASIC FLOW DIAGRAM FOR 260 INCH MOTORS AT THE MANUFACTURING SITE

FOR DISCUSSION REFER TO PAGE 6-89

FOR DISCUSSION REFER TO PAGE 6-89

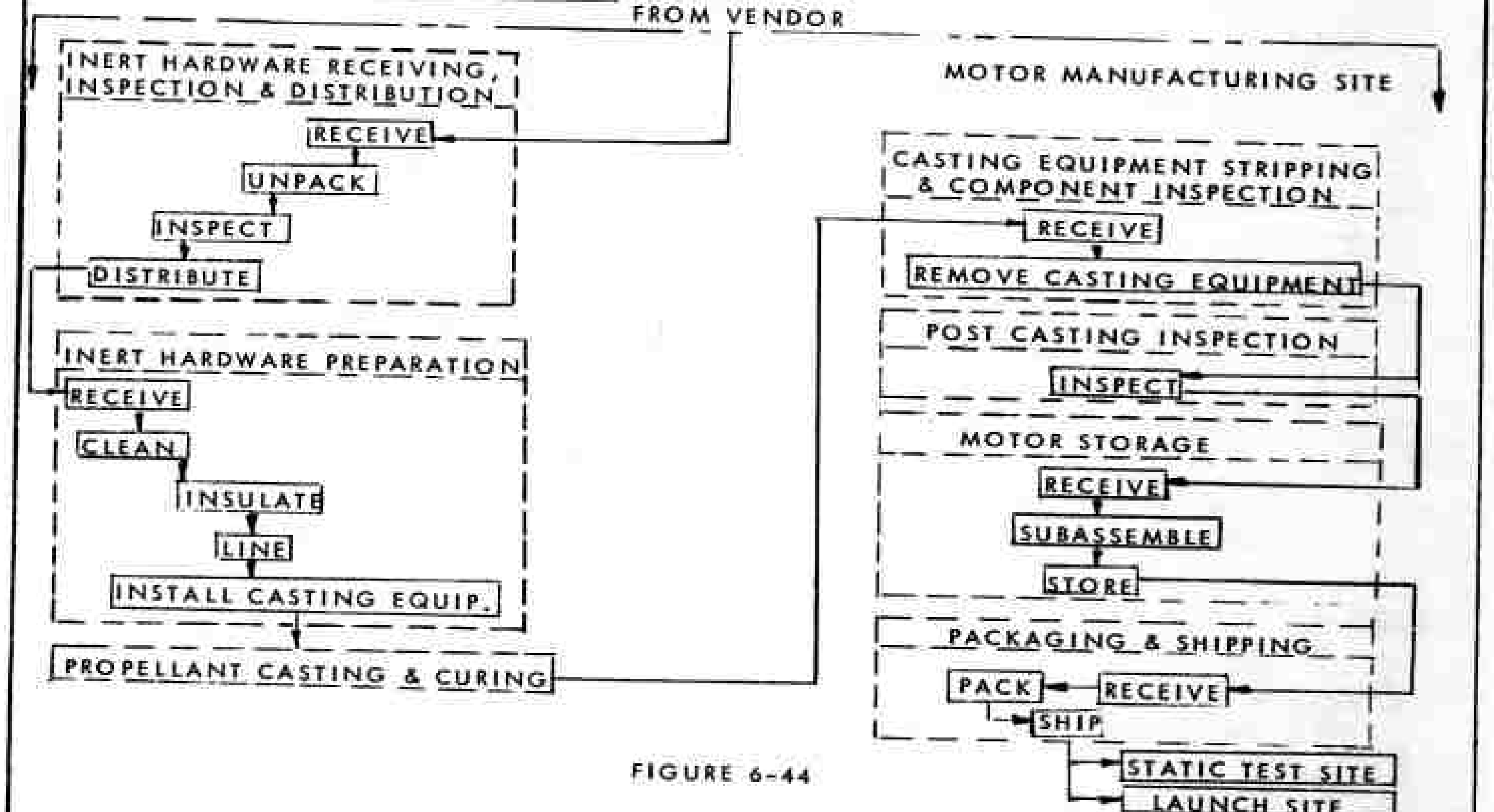


FIGURE 6-44

FUNCTIONAL FLOW CHART FOR 260 INCH MOTOR CASE HARDWARE AT THE MOTOR MANUFACTURING SITE

FOR DISCUSSION REFER TO PAGE 6-89

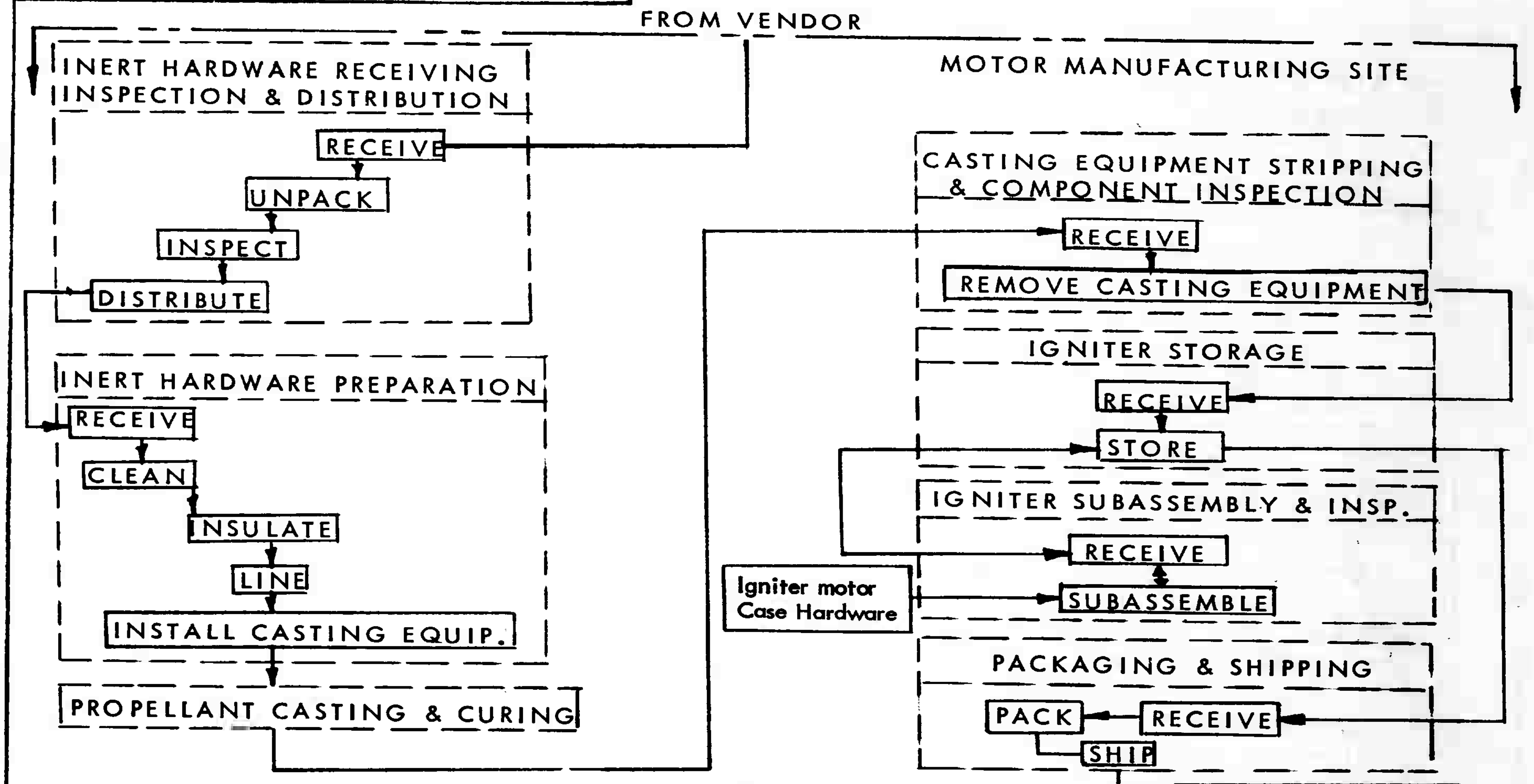


FIGURE 6-45

FUNCTIONAL FLOW CHART FOR 260 INCH MOTOR IGNITER MOTOR CARTRIDGE AT THE MOTOR MANUFACTURING SITE

FOR DISCUSSION REFER TO PAGE 6-89

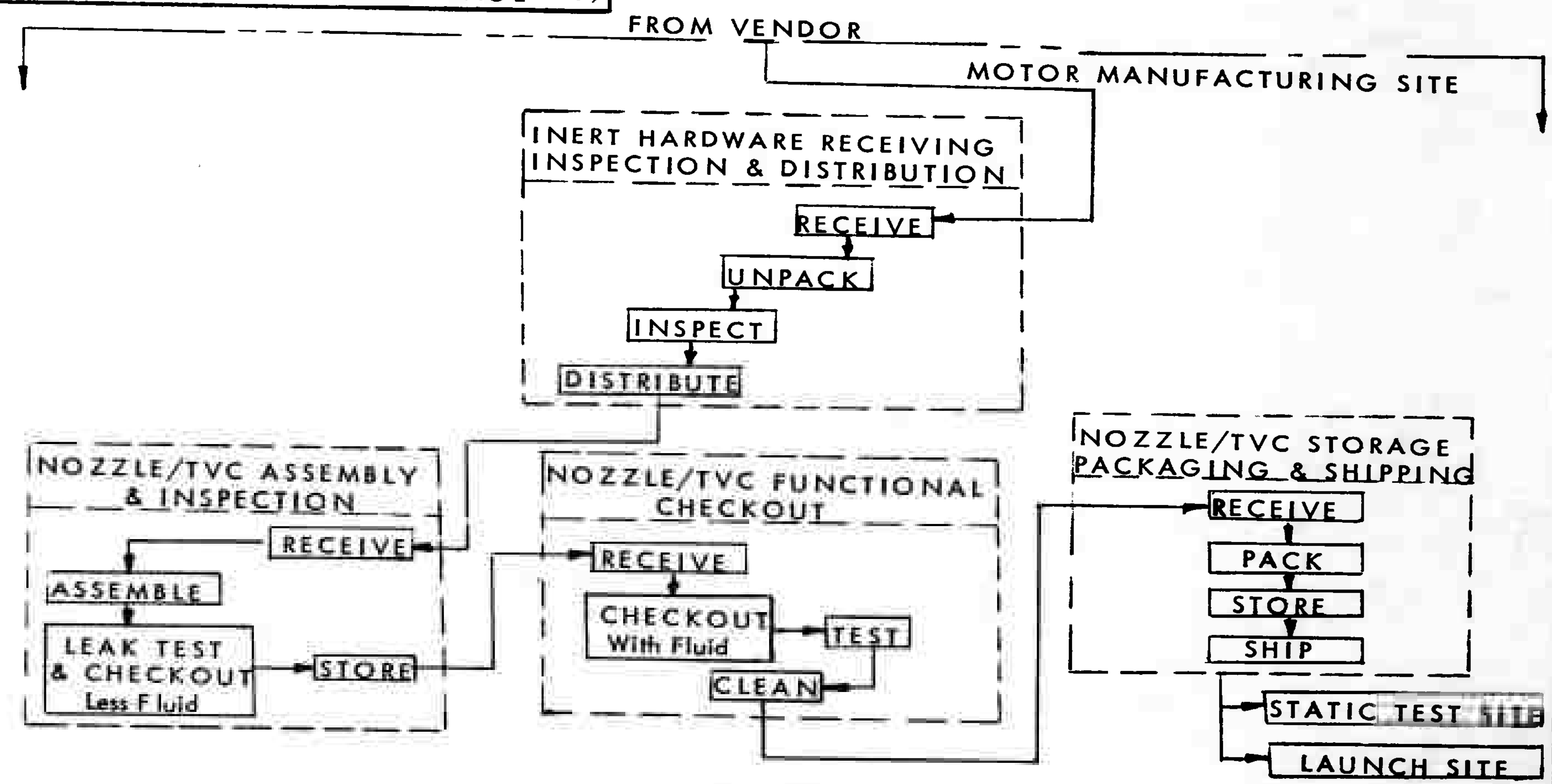


FIGURE 6-46
FUNCTIONAL FLOW CHART FOR 260 INCH MOTOR NOZZLE AND T.V.C. COMPONENTS AT THE MANUFACTURING SITE

FOR DISCUSSION REFER TO PAGE 6-89

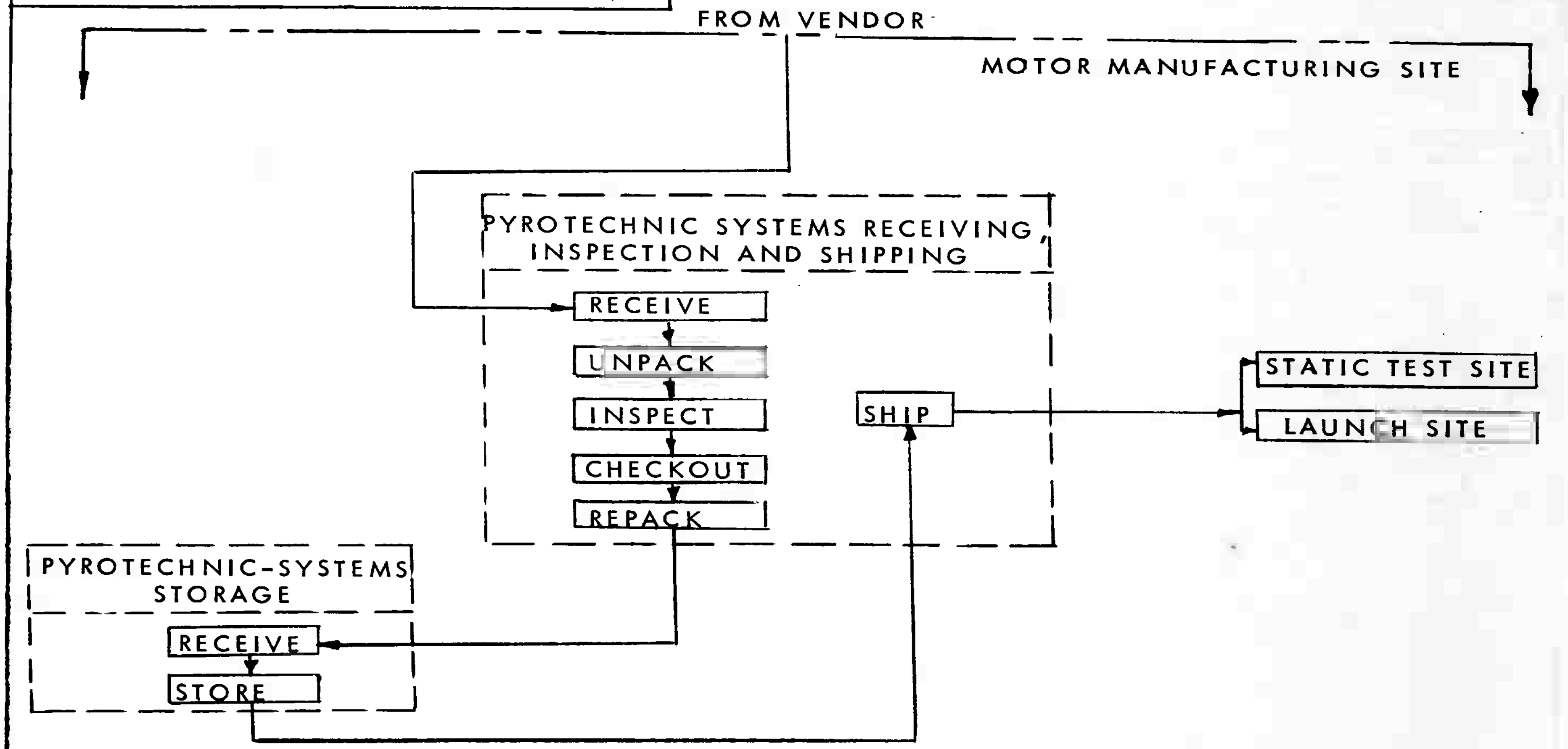


FIGURE 6-47

FUNCTIONAL FLOW CHART FOR 260 INCH MOTOR SAFE & ARMS, SHAPED CHARGES AND DETONATING FUSE TRANSFER AND JUMPER HARNESSES AT THE MOTOR MANUFACTURING SITE

FOR DISCUSSION REFER TO PAGE 6-89

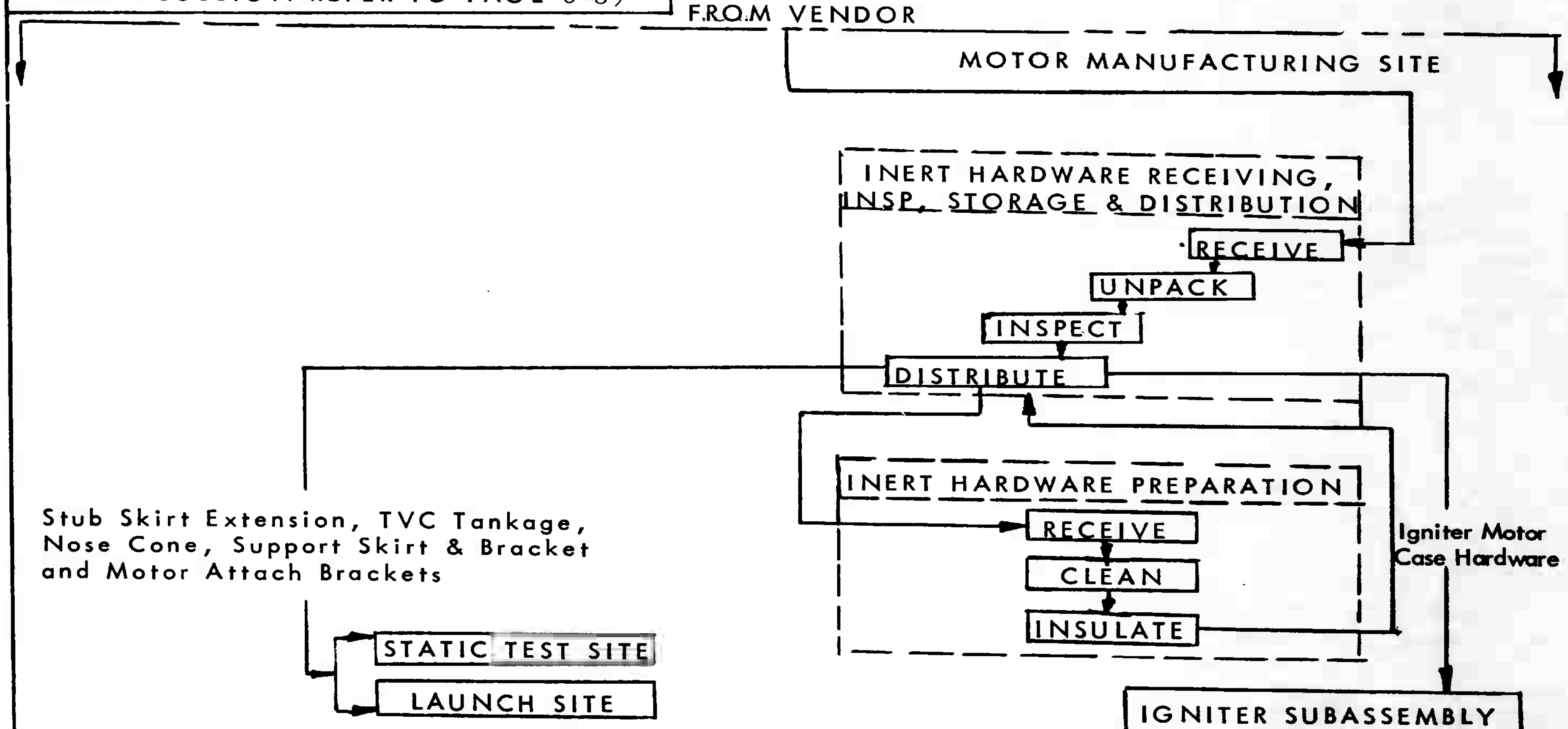


FIGURE 6-48

FUNCTIONAL FLOW CHART FOR 260 INCH MOTOR IGNITER MOTOR CASE HARDWARE, T.V.C. TANKAGE AND MOTOR SUPPORT AND ATTACH HARDWARE AT THE MOTOR MANUFACTURING SITE

FOR DISCUSSION
REFER TO PAGE 6-96

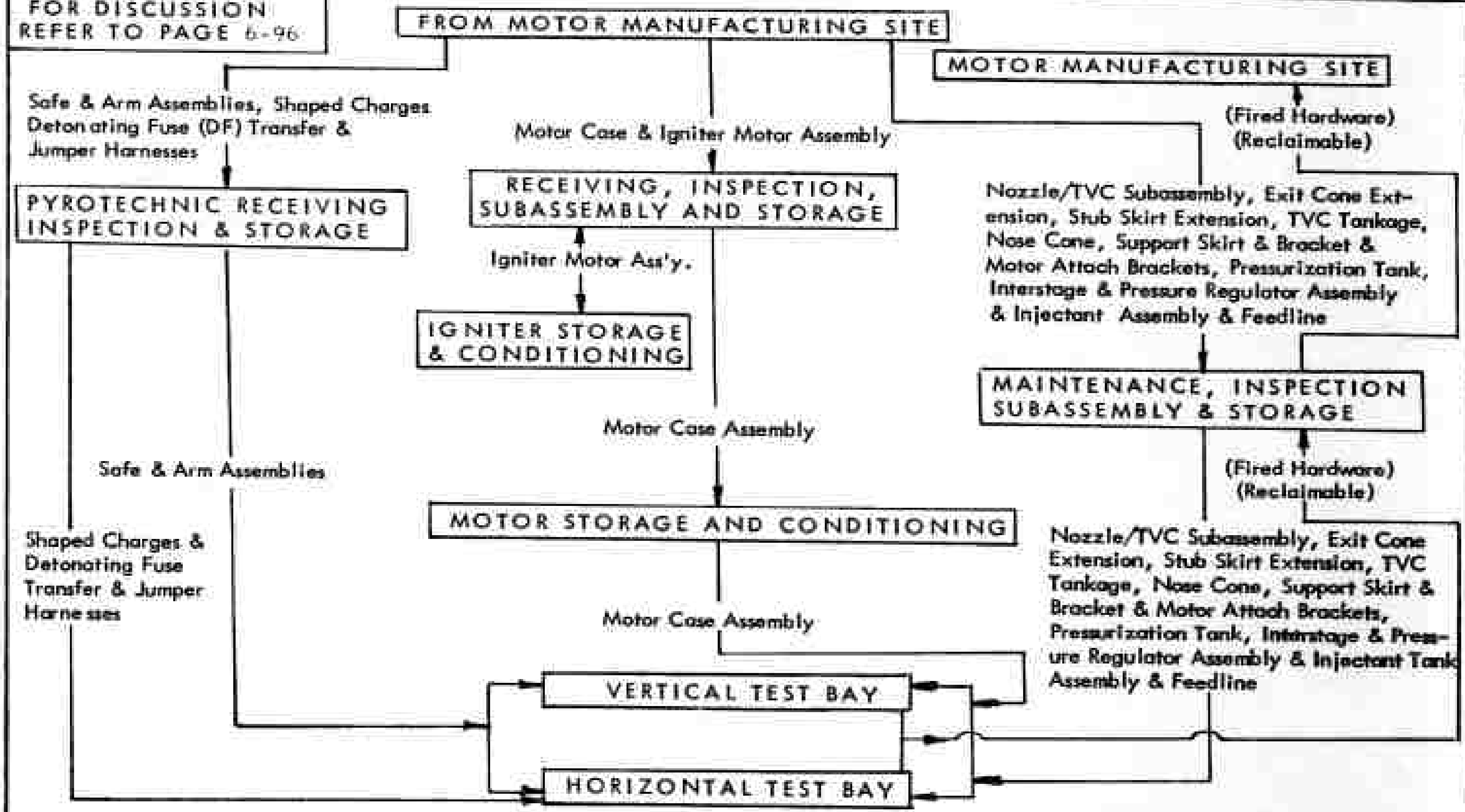


FIGURE 6-49
BASIC FLOW DIAGRAM FOR 260 INCH MOTORS AT THE STATIC TEST SITE

FOR DISCUSSION REFER TO PAGE 6-96

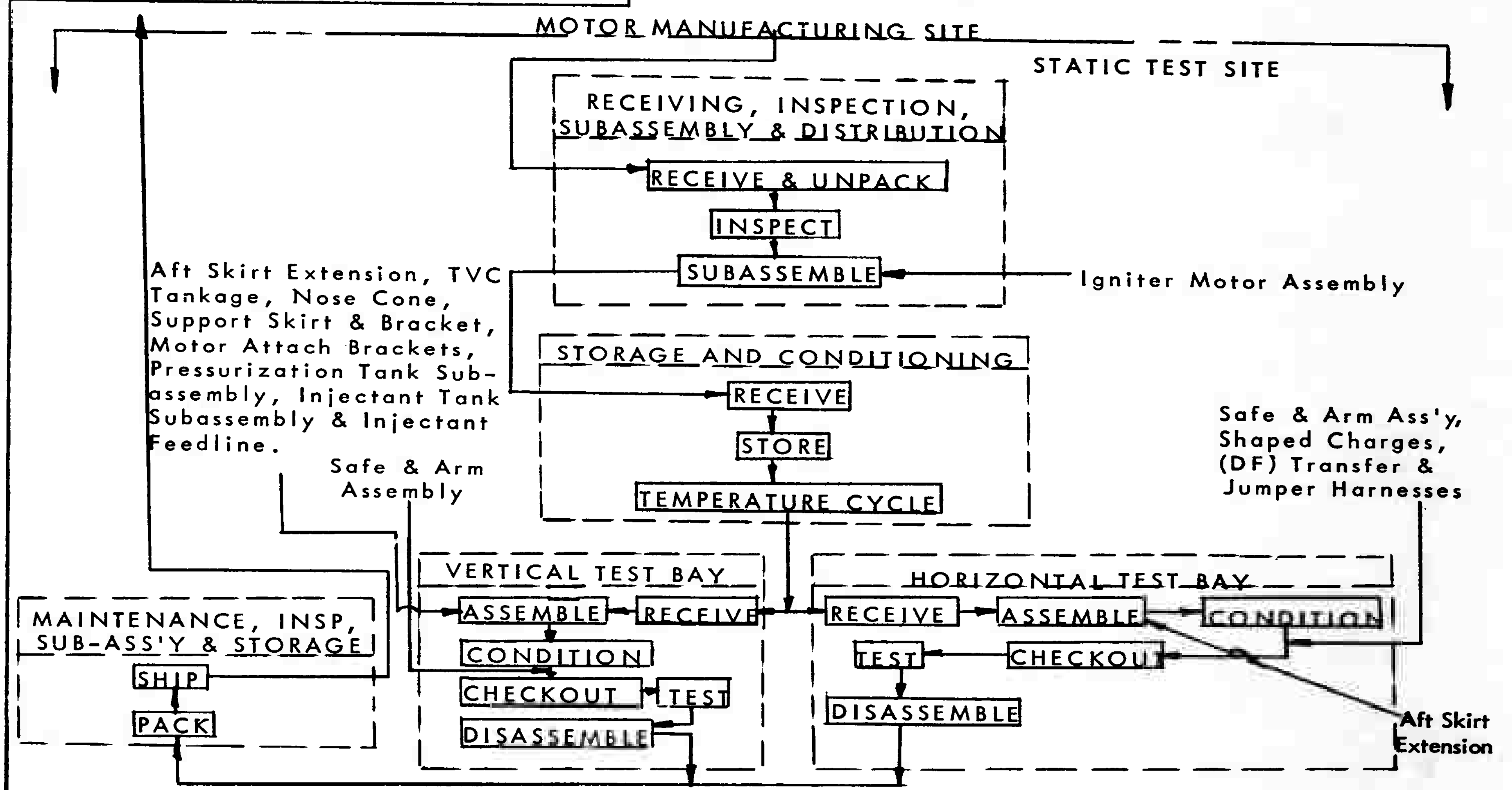


FIGURE 6-50

FUNCTIONAL FLOW CHART FOR 260 INCH MOTOR CASE AT THE STATIC TEST SITE

FOR DISCUSSION REFER TO PAGE 6-96

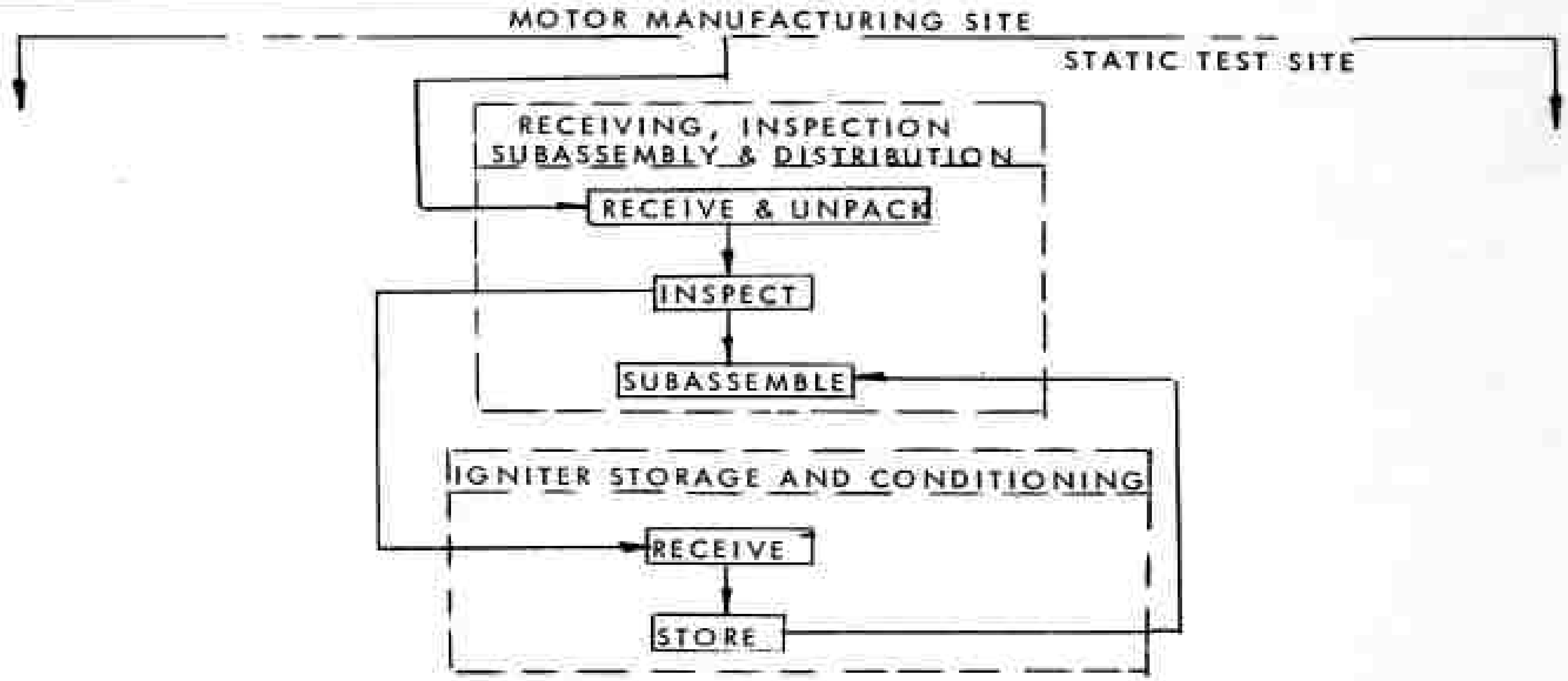


FIGURE 6-51

FUNCTIONAL FLOW CHART FOR 260 INCH MOTOR IGNITER MOTOR ASSEMBLY AT THE STATIC TEST SITE

FOR DISCUSSION REFER TO PAGE 6-96

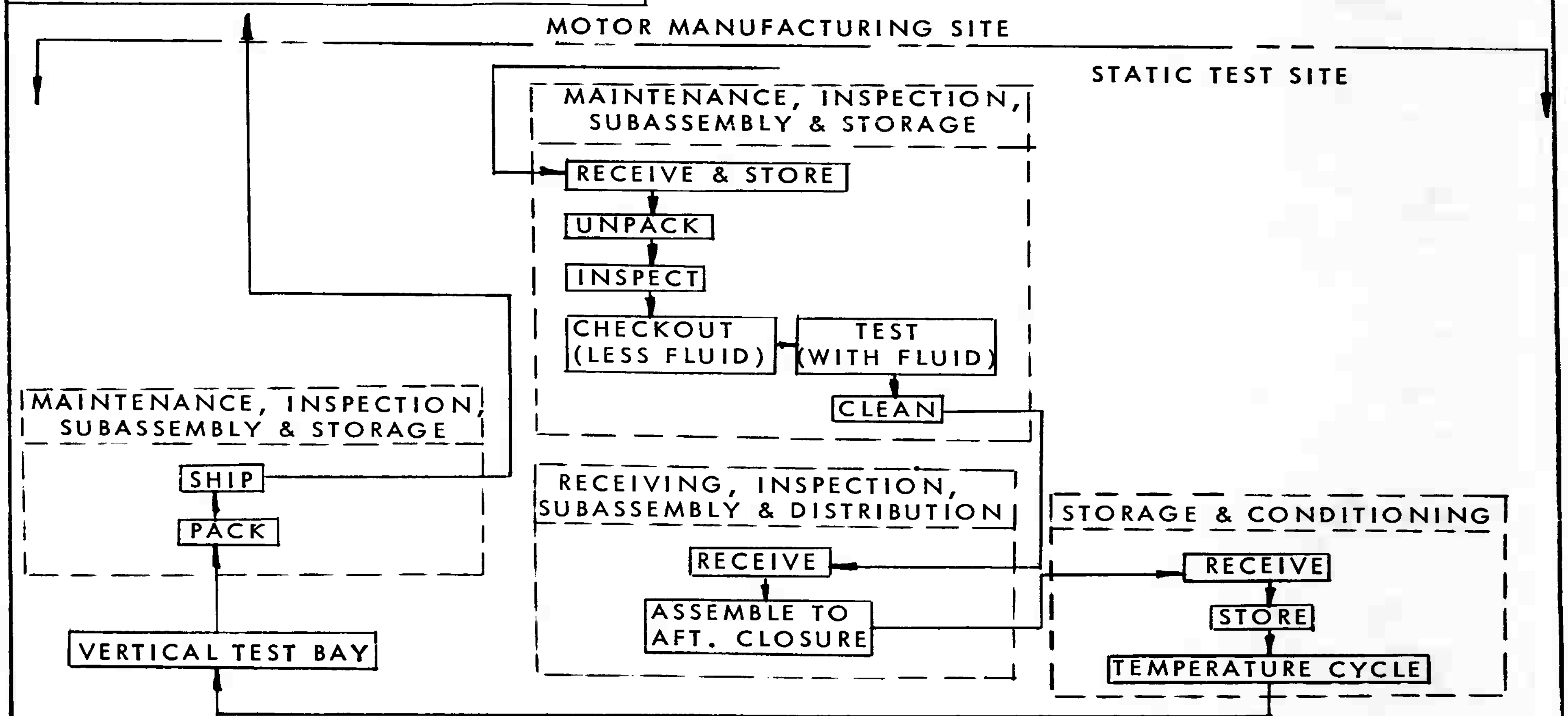


FIGURE 6-52

FUNCTIONAL FLOW CHART FOR 260 INCH MOTOR NOZZLE/TVC SUBASSEMBLY AT THE STATIC TEST SITE

FOR DISCUSSION REFER TO PAGE 6-96

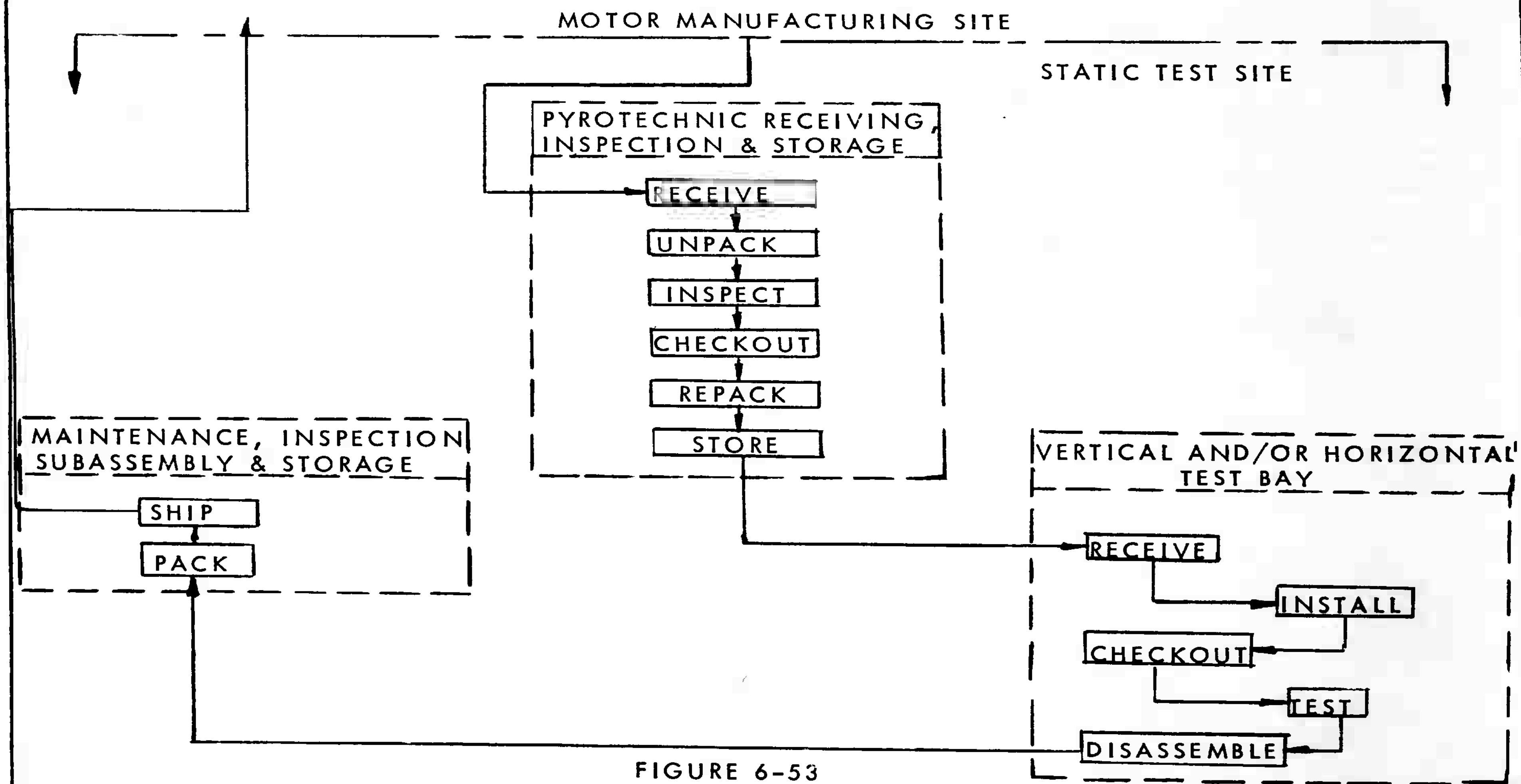


FIGURE 6-53

FUNCTIONAL FLOW CHART FOR 260 INCH MOTOR SAFE & ARMS, SHAPED CHARGES AND DETONATING FUSE TRANSFER AND JUMPER HARNESSES AT THE STATIC TEST SITE

FOR DISCUSSION REFER TO PAGE 6-96

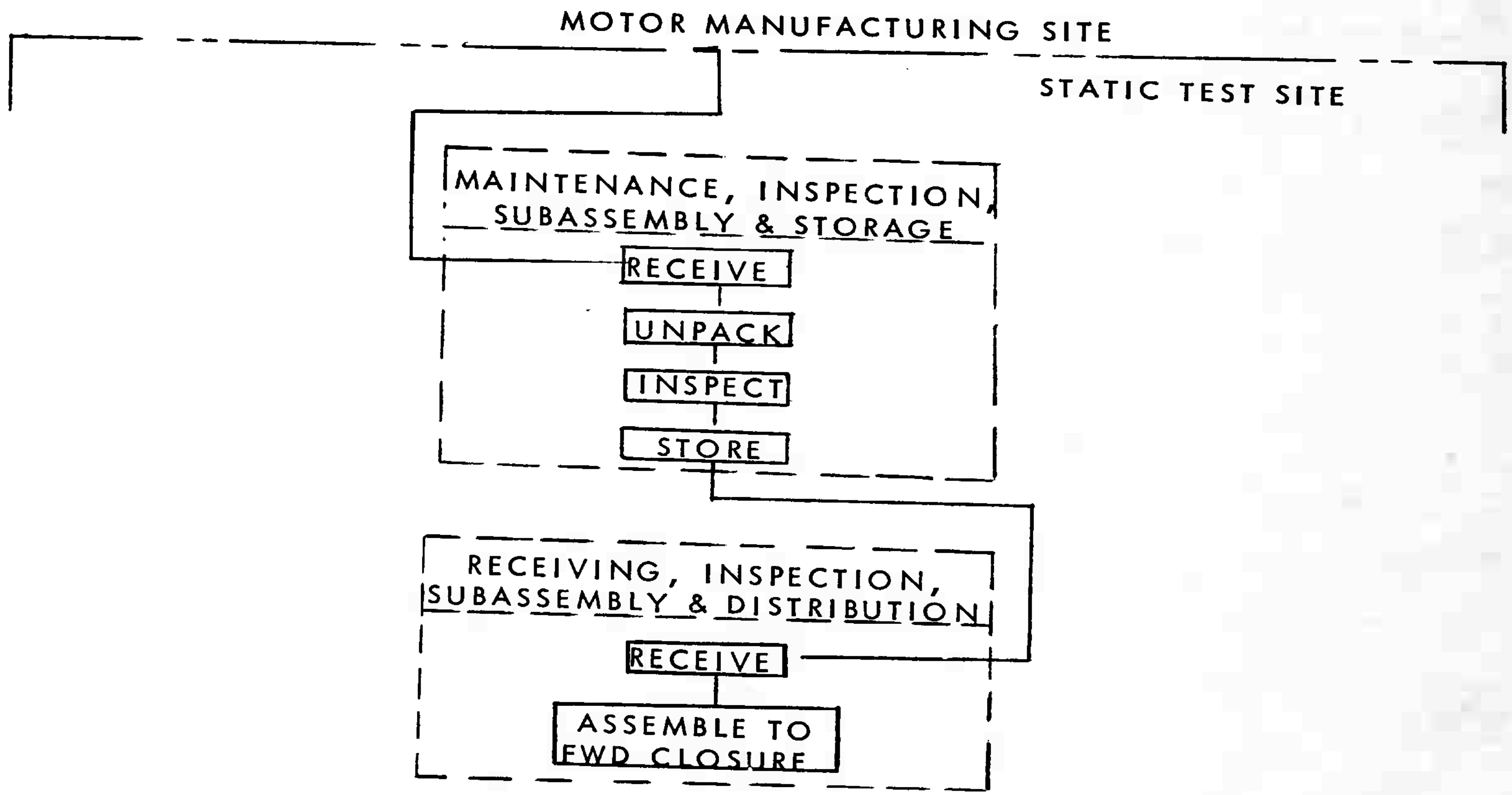


FIGURE 6-54

FUNCTIONAL FLOW CHART FOR 260 INCH MOTOR AFT SKIRT AND EXIT CONE EXTENSIONS, TVC TANKAGE AND MOTOR SUPPORT AND ATTACH HARDWARE AT THE STATIC TEST SITE

FOR DISCUSSION REFER TO PAGE 6-102

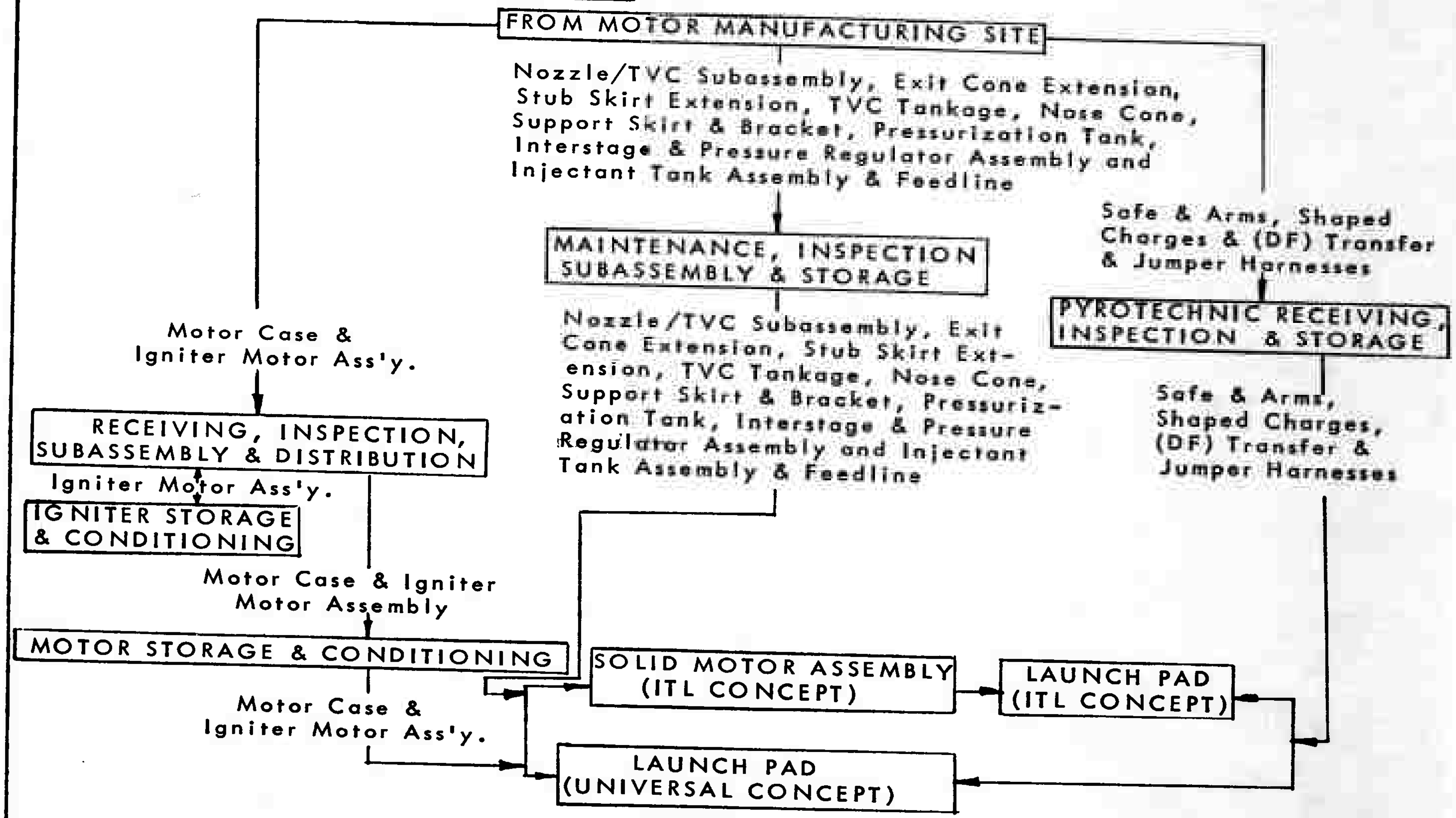


FIGURE 6-55

BASIC FLOW DIAGRAM FOR 260 INCH MOTORS AT THE LAUNCH SITE

FOR DISCUSSION REFER TO PAGE 6-102

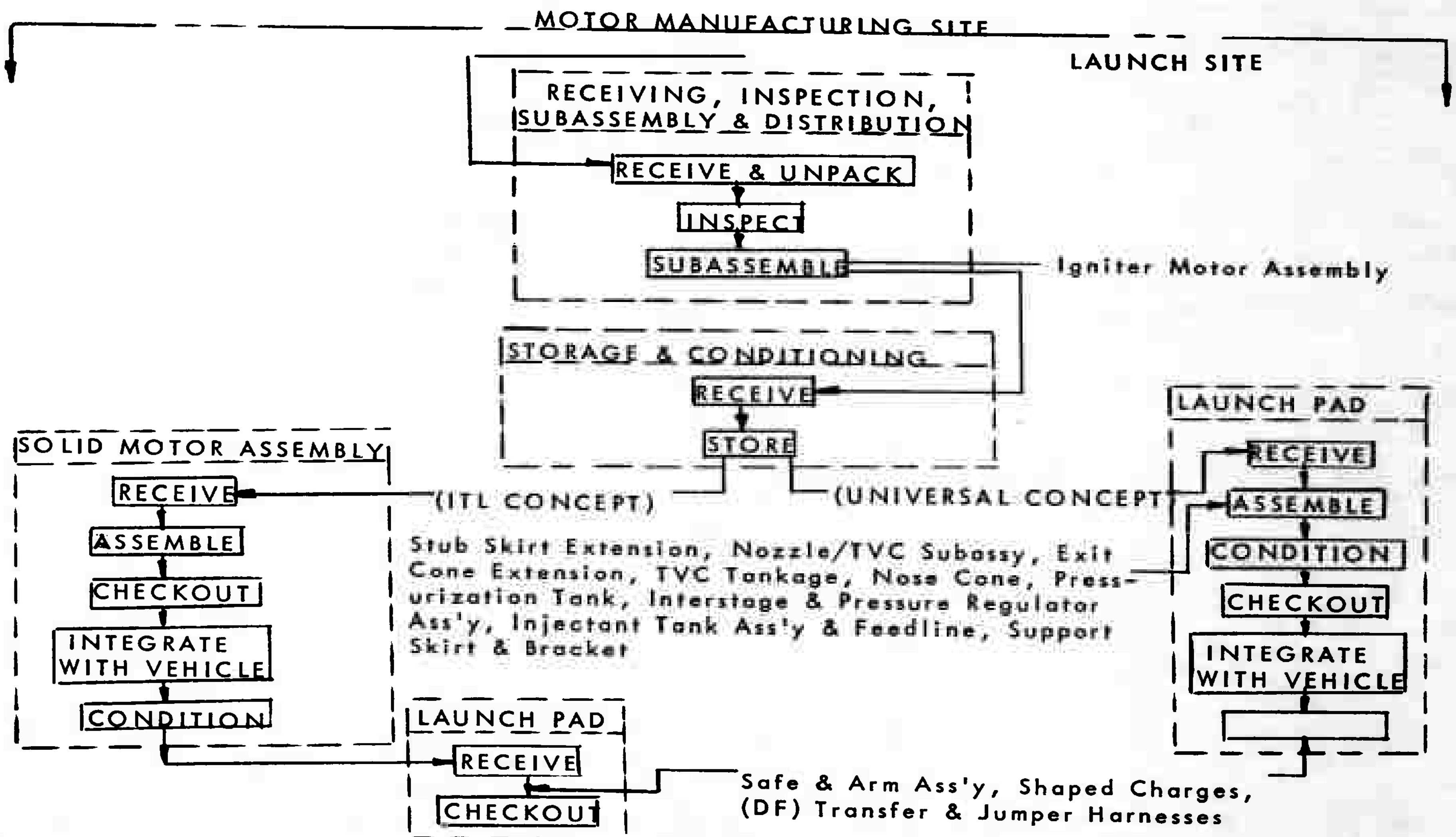


FIGURE 6-56

FUNCTIONAL FLOW CHART FOR 260 INCH MOTOR CASE AT THE LAUNCH SITE

FOR DISCUSSION REFER TO PAGE 6-102

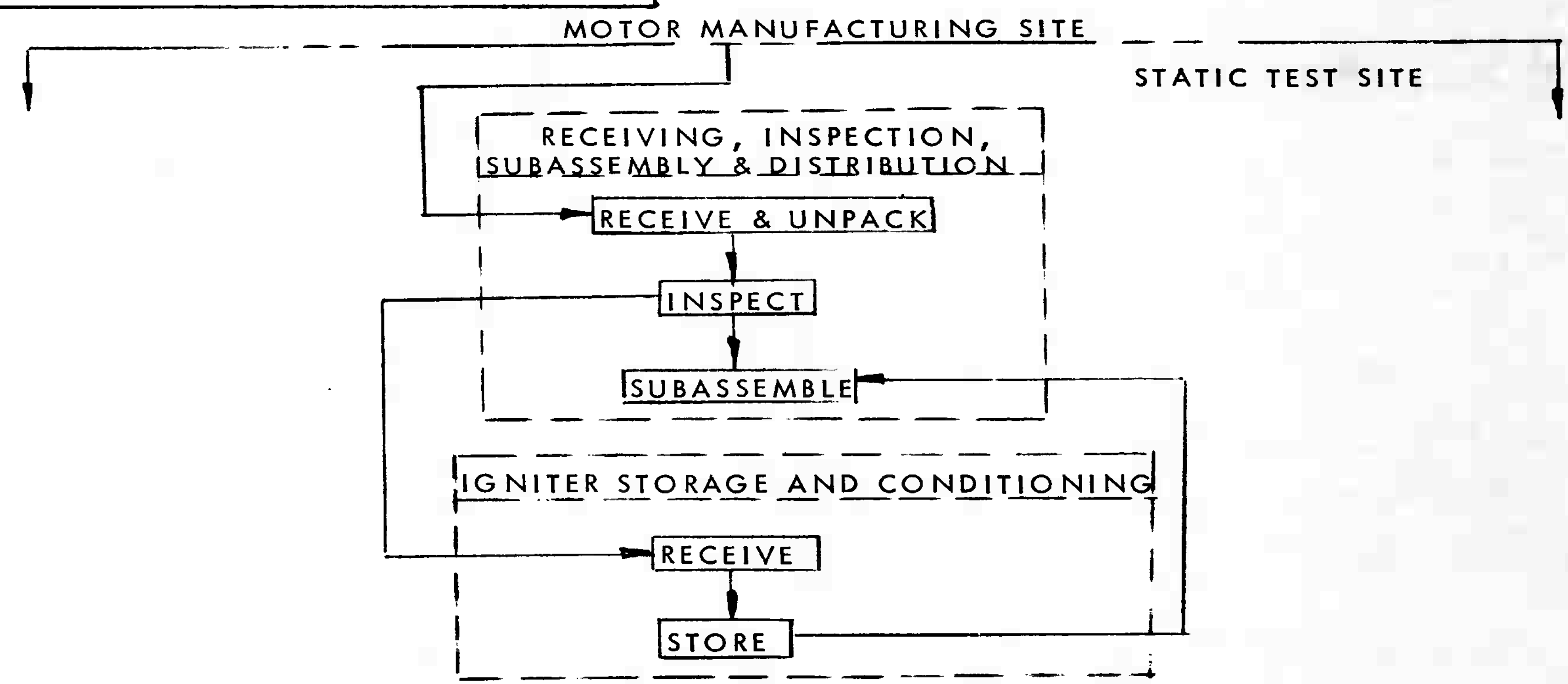


FIGURE 6-57

FUNCTIONAL FLOW CHART FOR 260 INCH MOTOR IGNITER MOTOR ASSEMBLY AT THE LAUNCH SITE

FOR DISCUSSION REFER TO PAGE 6-102

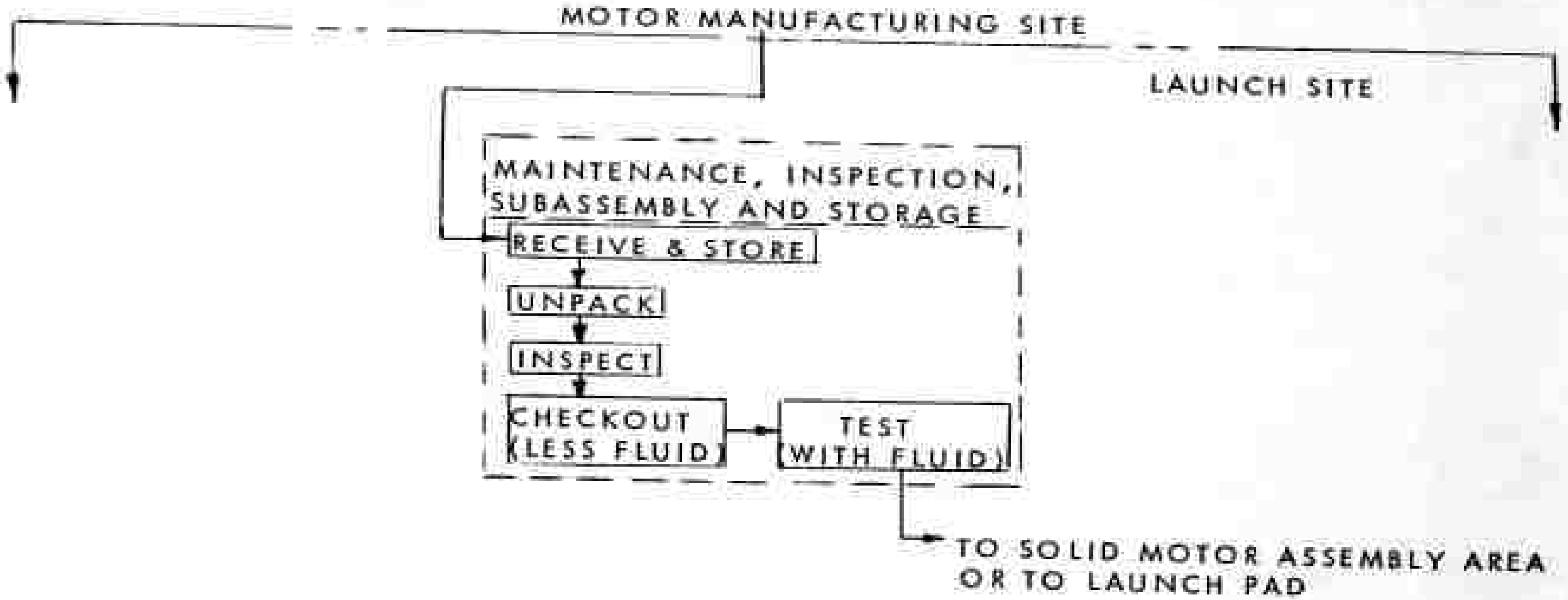


FIGURE 6-58

FUNCTIONAL FLOW CHART FOR 260 INCH MOTOR NOZZLE/TVC SUBASSEMBLY, AFT SKIRT & EXIT CONE EXTENSIONS, TVC TANKAGE AND MOTOR SUPPORT AND ATTACH HARDWARE AT THE LAUNCH SITE

FOR DISCUSSION REFER TO PAGE 6-102

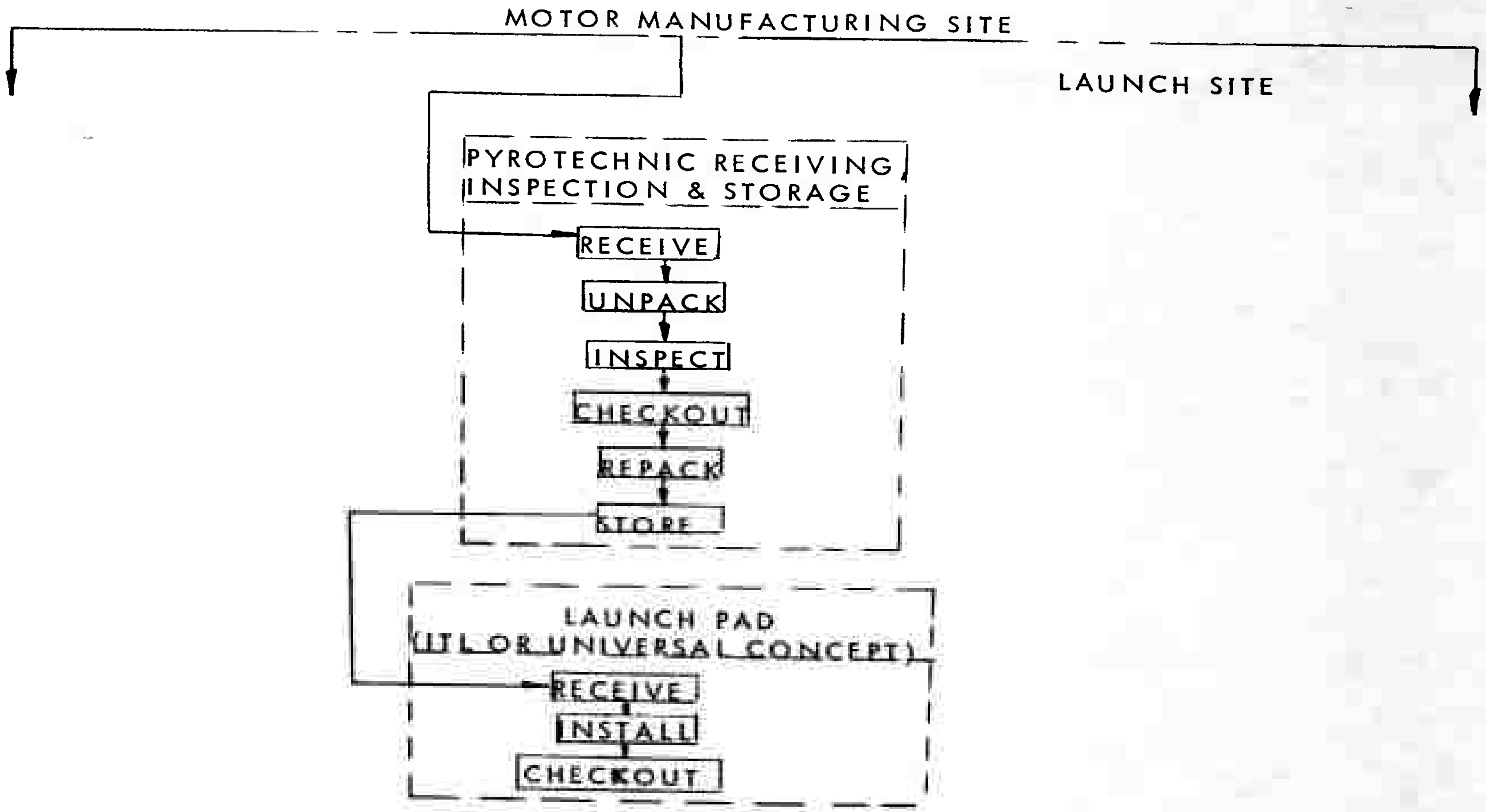


FIGURE 6-59

FUNCTIONAL FLOW CHART FOR 260 INCH MOTOR SAFE & ARMS, SHAPED CHARGES AND DETONATING FUSE TRANSFER & JUMPER HARNESSES AT THE LAUNCH SITE

SECTION 7
TYPICAL HANDLING EQUIPMENT FOR SOLID MOTORS

1. SEGMENTED MOTOR AGE

The equipment described below is applicable to both 120 and 156-inch motors. Particular help in supplying information for this Section was obtained from the Thiokol Chemical Corp., Wasatch Division.

Figure 7-1A, page 7-5 is a shipping container projected by AMF for a 120-inch diameter segment. The container will be used primarily to provide protection against all types of weather extremes (rain, snow, wind, heat, cold, etc.), and could, if required, provide small arms protection. The base of the container serves as a handling harness to provide shock protection during in-plant handling. This harness would be installed immediately after the initial inspection process and would form the base of a segmented, insulated shell structure which may be assembled around the segment on the handling harness without any need for hoisting the segment.

Two duct connections are provided to couple the container to an external environmental control unit. The control unit will supply conditioned air to the container during the trip or during storage to maintain the required temperature and humidity conditions. Sensing units (thermocouples, humidistats and accelerometers will be provided to sense the environment to which the segment is subjected while in the container. The output of the sensing unit will be fed to an events recorder containing continuously-moving strip charts. This will provide a permanent record of all conditions encountered throughout segment transport. The base of the shipping container, as concepted, is compatible with the roller dolly system to be used for in-plant and launch complex segment transport. The blow out diaphragm permits easy access to the segment during inspection, without removing the bottom handling harness. It also enables removal of the events recorder without the necessity of container disassembly. If required, small arms protection could be provided.

For transport of segments in the horizontal attitude (as required for 156-inch diameter segments) AMF has projected the concept in Figure 7-1B, page 7-5. In this scheme the base of the shipping container serves as a cradle for the segment. The cradle is installed after the initial inspections and makes the segment compatible with the roller dolly projected in Figure 7-2A, page 7-6.

The segment is supported intermittently throughout the length of the cradle. A rubber liner is added to these intermittent supports for cushioning in the radial direction. The remainder of the shipping container is assembled around the segment without its being lifted. Axial shock protection for long line transportation , if required, would be provided via laminated rubber shock rings. Environmental conditioning and recording equipment will be provided as in the 120-inch shipping container.

Figure 7-2A, page 7-6 is the AMF roller dolly referred to throughout this report. This dolly is capable of transferring motor segments from station-to-station without their having to be lifted. A roller/winch system on the dolly permits rapid loading and unloading. The dolly is equipped with leveling and stabilizing jacks to permit accurate alignment between the dolly and the unloading point. Handling of larger segments would be accomplished with a dolly of similar design. Additional wheels would be provided to accommodate the heavier loads. Another possibility would be to design the dolly so that it could handle either one large segment (in the horizontal attitude) or two smaller segments (in the vertical attitude). The only change required would be the addition of extra roller conveyors (four instead of two). An additional advantage of the roller conveyor dolly is that the segments can be placed in storage without the use of a crane and without the dolly remaining with the segment.

Figure 7-2B, page 7-6 , is a segment handling harness and wheel assembly projected by the Wasatch Division of Thiokol Chemical Corp. The harness projected will support the segment and will be compatible with all manufacturing, transfer, inspection and testing operations. It is designed for use during both in-plant and field operations. The segment harness consists of two rigid end rings of split construction connected by side beams for segment support and weight distribution. Provision for case rounding will be built into the end rings. Trunnions attached to the side beams provide lifting, breakover and segment tie-down provisions.

The harness wheel assembly will support the segment during storage and horizontal roll transfer as well as during all transport operations. The wheel assemblies will connect directly to the harness end rings, and will be compatible with all harness units. For 120-inch diameter segments, the harness wheel assembly will consist of four 8-inch, 12,500-lb. capacity "V" grooved casters mounted on a simple walking beam type structure. This beam structure will be mounted to a support pedestal at a central pivot point. The support pedestal will be mounted through a spherical thrust bearing to a compression-type vibration isolation mount. The mount will be an integral part of a bracket that can be connected to the harness ring. The pivoted walking beam, acting with the spherical thrust bearing, will provide equal load distribution to

all four wheels in the caster assembly.

Figure 7-3, page 7-7, projects the addition of a rotating inspection platform to the roller dolly discussed above, thus permitting the dolly to serve the dual function of transport vehicle and inspection stand. This concept is a typical example of multi-purpose equipment.

As an example of a typical lifting beam, Thiokol Chemical Corp. has supplied Figure 7-4A, page 7-8. This loaded segment lifting beam will be used to lift the motor segments both vertically and horizontally. It will also be used to transfer the segments from horizontal to vertical attitude. This kind of beam would be used for in-plant manufacturing, inspection, assembly, and test operations as well as for assembly operations at the launch complex. Two hangers will be provided on the beam for attachment to the segment harness trunnion for breakover and vertical lifting operations. Four hangers will be used for horizontal lifting.

Figure 7-4B, page 7-8, also supplied by Thiokol Chemical Corp., is a fixture to measure case roundness. This fixture will be used to check the roundness of the joint area of the case prior to the assembly of two segments. By performing this check, any out-of-roundness that may be present in the joint area of the case can be eliminated by auxiliary rounding fixtures and the segments can be assembled with a minimum of difficulty. The roundness check fixture will be operated by using a hand crane to run the indicator around the circumference of the case. Any out of roundness will be read by a displacement transducer. The frame of the fixture could be fabricated from light, square tubing to keep its weight to a minimum.

Due to the temperature and humidity requirements imposed on solid propellant motors, AMF has proposed the use of environmentally-controlled blankets for the solid motors during the transport and storage operations which may be required at the launch complex. (See Figure 7-4C, page 7-8). This blanket will be used to:

1) Protect the assembled solid propellant motor from the effects of rain, snow, sand, etc.

2) Provide the assembled solid propellant motor with properly conditioned air in order to keep it within the specified temperature and humidity requirements.

The blanket will consist of a number of sections joined to each other by appropriate devices to make it essentially airtight. Each section will consist

of multi-layered fabric designed to inhibit heat transfer between the motor side and the exterior side, and to allow forced circulation of conditioned air from the conditioning unit to the motor surface and return.

Supply and return of the air will be arranged to insure a uniform temperature over the entire motor surface. The blanket will be fitted with appropriate spacers between the motor surface and the innermost blanket layer and between the innermost blanket layer and the exterior insulating layer to provide for adequate passage of supply and return air.

The external insulating layer will consist of an exterior solar radiator-reflecting surface layer, an intermediate moisture barrier, and an inner thermal-insulating layer. The entire assembly will be fitted with appropriate thermocouples and humidity sensing devices to control the operation of the air conditioning unit.

Another essential piece of equipment, the mobile hoist, is concepted in Figure 7-4D, page 7- 8 . This device is used to install and remove the segment handling rings and to aid in container emplacement. The capacity of the device shown is approximately five tons at a 5. 5 ft. radius. It is a pneumatic-tired device with an explosion proof motor. The minimum hook height is 12 ft. This particular hoist is listed in the Federal Stock List as No. 3950-272-9080, Model C2.

FOR DISCUSSION REFER TO PAGE 7-1

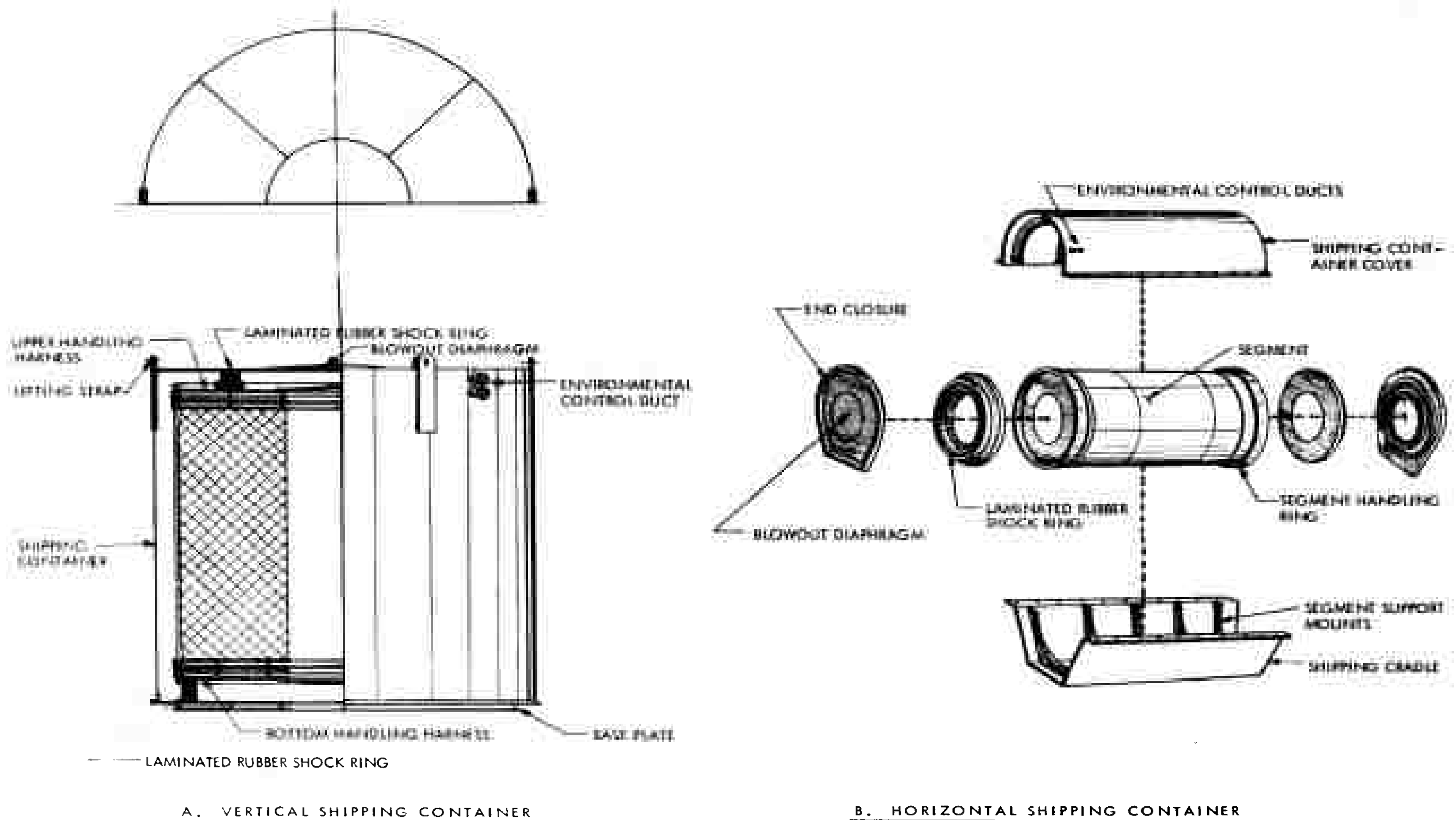
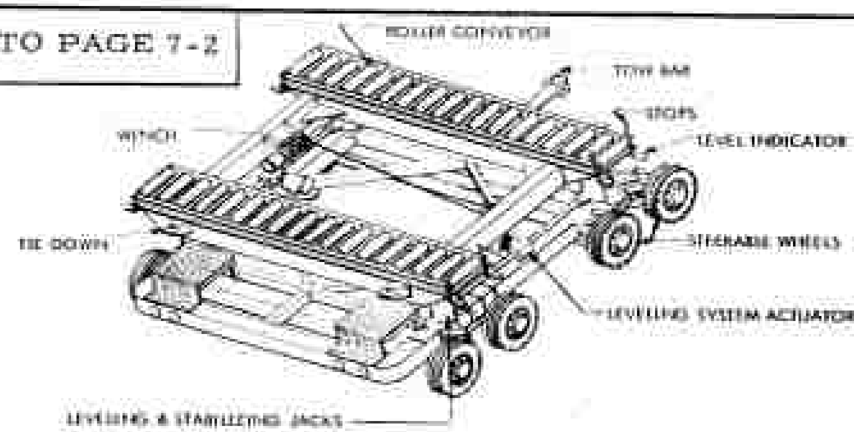
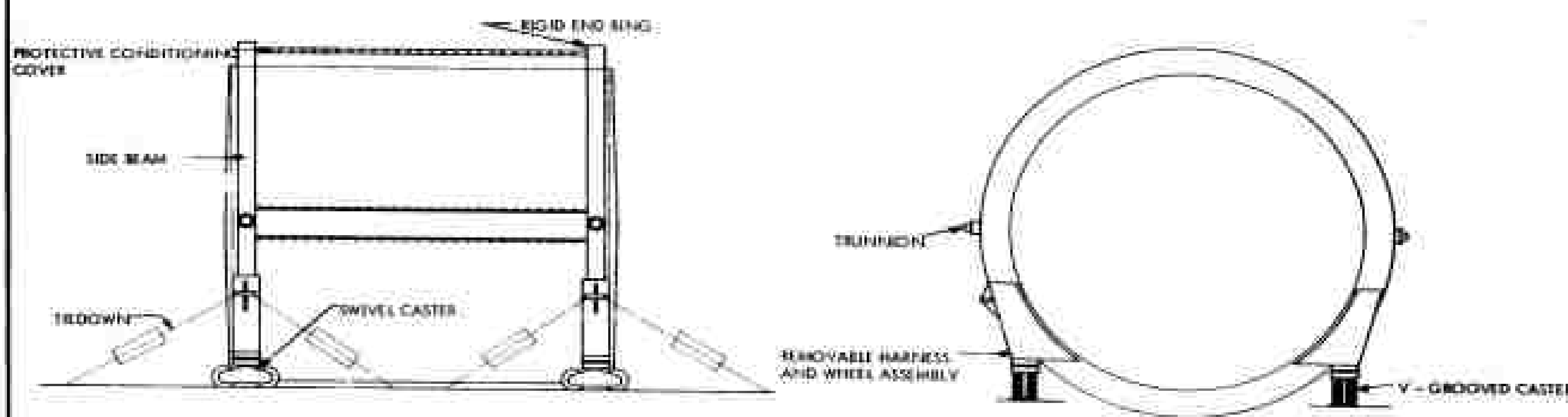


FIGURE 7-1
SEGMENT SHIPPING CONTAINERS

FOR DISCUSSION REFER TO PAGE 7-2



A. AMF SEGMENT ROLLER DOLLY



B. SEGMENT HANDLING HARNESS AND WHEEL ASSEMBLY (SUPPLIED BY THIOKOL CHEMICAL CORP.)

FIGURE 7-2
SEGMENT HANDLING DOLLIES

FOR DISCUSSION REFER TO PAGE 7-3

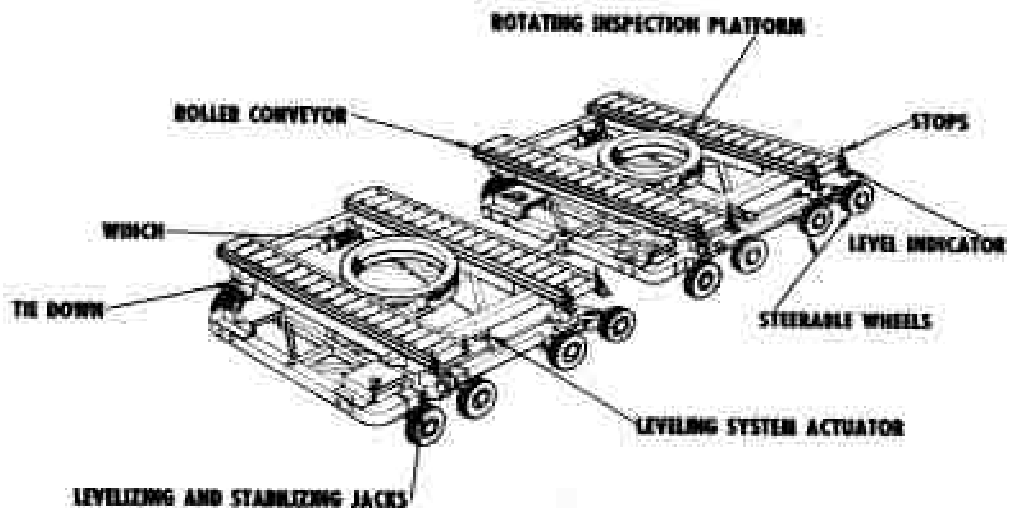


FIGURE 7-3
MULTIPURPOSE HANDLING & INSPECTION DOLLIES

FOR DISCUSSION REFER TO PAGE 7-3

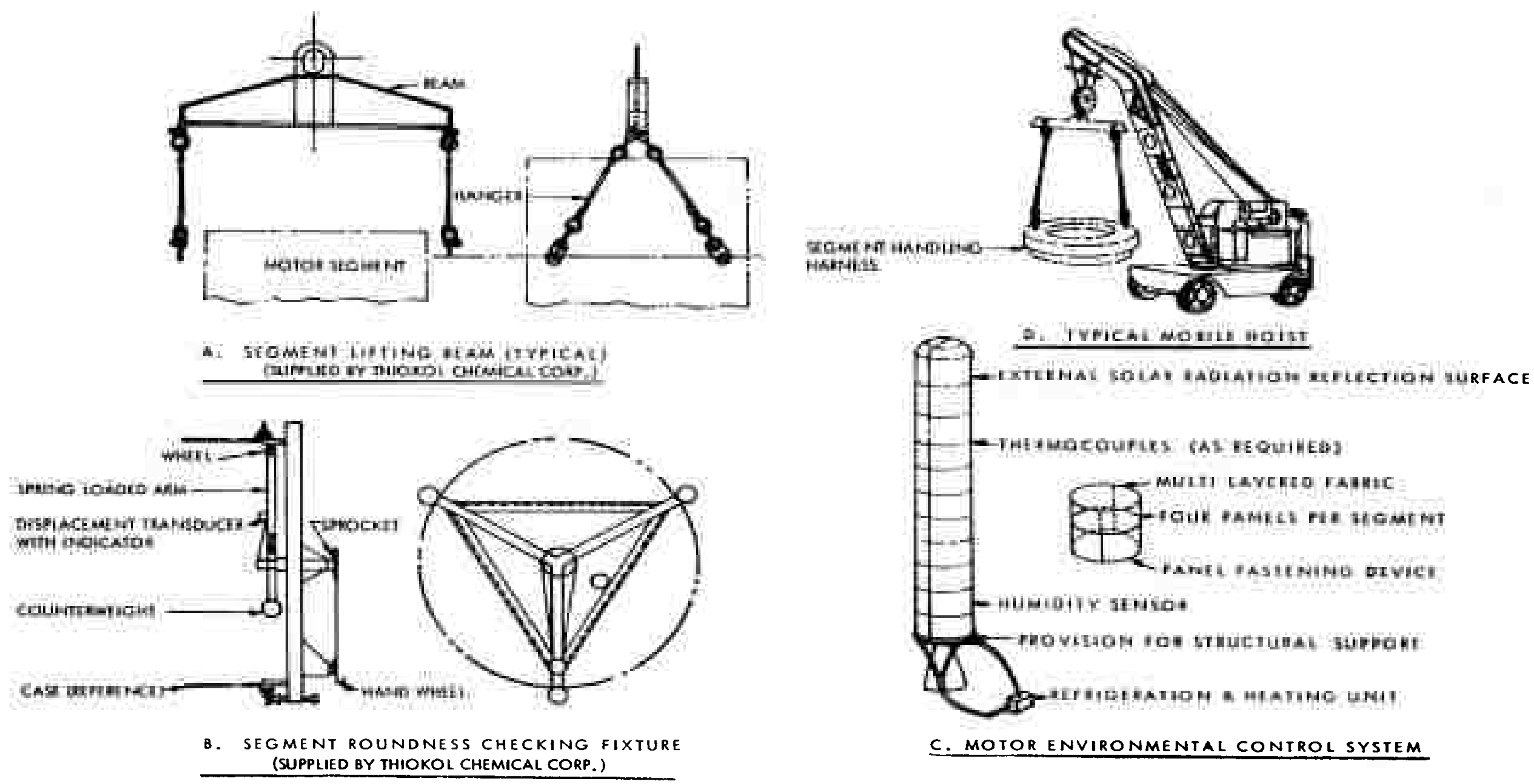


FIGURE 7-4
MISCELLANEOUS A. G. E.

2. TYPICAL AGE FOR THE 260-INCH MONOLITHIC MOTOR

Sections 5 and 11 discuss the concepts which have been proposed for the handling of monolithic motors and boosters at the manufacturing, static test and launch sites. Due to the large number of possible handling concepts, AGE for the 260-inch monolithic motor can be discussed only in very general terms.

a. Transport of Empty Motor Cases.

This will be performed by barge or by direct floatation. Since the probable location of the manufacturing/static test site will be near water. The case can be loaded aboard the barge by an overhead crane, by transporter, or by floating it aboard in a semi-submerged vessel. Figure 5-18A, page 5-52 shows a caisson shipping container and a structural suitcase capable of loading the motor case onto a barge. These items are discussed in Section 5.

b. Motor Manufacturing and Static Test.

Methods discussed in Section 5 are essentially divided into two categories:

1) Dry Methods - Methods in which the motor case is unloaded off a barge, erected and placed in a facility prior to being filled with propellant. (Refer to Figures 5-20 through 5-23, pages 5-54 through 5-57).

2) Wet Methods - Methods which use floatation techniques to erect the case prior to filling it with propellant. (Refer to Figure 5-30, page 5-64).

Equipment for the Dry Methods would include the following:

1) Erection Equipment - Gantry or Transporter Erector.

2) Emplacement Equipment - Hydraulic Jacking system for lowering the case onto a prepared foundation.

3) Propellant Loading Equipment - Cranes and Hoppers.

Equipment for the Wet Method would include:

1) Water-tight floatation caisson.

2) Guide rails for erection of caisson.

3) Propellant loading equipment as above.

The equipment mentioned above for the erection of the motor case must of course be sized so that it can be used for the horizontal placement of the loaded motor onto the barge or into the water-tight floatation caisson and for its eventual transportation to the launch site.

c. Launch Site Handling.

Section 11 discusses, in the detail, the various handling concepts for the 260-inch monolithic motor at the launch site. (Refer also to concepts shown in Figures 5-34 through 5-43, pages 5-68 through 5-76). Typical equipment can be categorized as follows:

1) Erection - Gantry (stationary or movable) or CG Pivot type Transporter Erector.

2) Transportation to the Launch Pad - Horizontal or vertical transporter.

3) Clustering on the Pad - Gantry at pad or vertical transporter for single motor.

4) Clustering off the Pad - Gantry or transporter erector, and booster transporter.

SECTION 8
HANDLING EQUIPMENT – GENERAL

1. CRANES

Tables 8-1 and 8-2, pages 8-9 and 8-10 are supplied as general information on available cranes. The Table gives the types of cranes capable of handling a desired load and the source of information.

Figure 8-1, page 8-14 contains drawings and descriptions of the following types of high capacity cranes.

Gantry Crane	Overhead Traveling Crane
Cantilever Gantry Crane	Portal Crane
Hammerhead Crane	Tower Crane

Table 8-3, page 8- 1 gives the general operating characteristics for the above-mentioned cranes.

Descriptions and sketches of mobile cranes can be found in Figure 8-2, page 8-15. Locomotive, crawler, truck and floating cranes are included. The general characteristics of these cranes can be found in Table 8-4, page 8-12. Figure 8-3, page 8-16 supplies descriptions and sketches of the following types of derricks:

A-Frame Derrick	Guy Derrick
Stiffleg Derrick	Gin Pole Derrick

The operational characteristics of these derricks can be found in Table 8-5, page 8-13. The Tables mentioned above provide such information as feasible sizes, lifting capacities and suitability of the piece of equipment for the operation desired.

The terms used are relative and the quantities approximate. The conditions affecting each application in the field are so numerous and the possible modifications so varied that only generalizations are of any value in comparing one type of machine with another. Reference: Design Manual - Weight Handling Equipment and Service Craft, NAVDOCKS, DM-38, 19 February 1962.

A typical example of a gantry crane now in use can be found in Figure 8-4, page 8-17. This 310-foot mobile service tower (weight - 2800 tons) was

designed and constructed by Kaiser Steel for Saturn Pad-34 at Cape Canaveral. This type of gantry is representative of that now in use in conjunction with on-pad assembly of large space vehicles. The tower is supported by four 12-wheeled trucks on rails and is capable of withstanding winds of 125 miles per hour without the use of guy wires. It is also capable of moving against winds of 46 miles per hour. As part of its equipment, the tower will carry a 60-ton capacity crane (hook height - 245 ft.), five movable service platforms, and three elevators. In addition, it contains its own power station, air conditioning, fire protection, intercom, water, air and lighting facilities, complex operating controls and lightning protection. The project value, as supplied by Kaiser Steel Corp. of Oakland, Calif., is 3.9 million dollars.

Figure 8-5, page 8-18 represents the world's largest stripping shovel which is currently being manufactured by the Bucyrus Erie Corp. of South Milwaukee, Wisconsin. The Crawler Transporter which is part of this shovel is capable of supporting 16 million pounds. This type of crawler will be used by NASA for transporting the Saturn C-5 Configurations at Cape Canaveral. In answer to AMF's letter survey, Bucyrus Erie suggested the possibility of utilizing the lower portion for mounting a hoisting unit. As an example, they suggested their 1850 B unit (weight - 8.5 million pounds) as being capable of supporting a hoist with a 1600 ton lifting capacity. Any hoisting capability in excess of 1600 tons could be handled by their 3860 B unit (weight - 16 million pounds).

Figure 8-6, page 8-19 was supplied by Bucyrus Erie Co. It depicts a gantry capable of handling 800 tons. The configuration of the gantry was supplied to Bucyrus Erie by the Nashville Bridge Co. The loaded weight of the structure is 4.1 million pounds. The bearing area of the crawler treads is approximately 85,500 square inches, thus inducing a ground pressure of 48 psi. The travel speed of the crawler-mounted gantry is about 20 feet per minute or .23 miles per hour. Figure 8-7, page 8-20 was also supplied by Bucyrus Erie Co. The gantry depicted is capable of supporting a load of 1,600 tons. The gantry configuration is based on a Nashville Bridge Co. drawing. The gantry itself weighs 3.2 million pounds while the crawler's weight is 2.3 million pounds. A total weight of 8.7 million pounds is realized when considering a maximum lift. The bearing area of 165,000 square inches limits the ground pressure to 53 psi. The travel speed of this device is the same as that of the 800 ton unit.

Examples of readily available floating cranes can be found in Figure 8-8, page 8-21. The capacities and critical dimensions are also included on the drawing which was supplied by the New York Naval Shipyard.

2. JACKS

Figure 8-9, page 8-22 , supplied by the DeLong Corp., is a pictorial representation of the sequence of operations associated with their hydraulic jacks.

The capacities of these jacks range between 500 and 800 tons. A 1000-ton jack has been designed, but has not been built to date. These jacks can be arranged to provide four jacks at each lifting point. Thus, a system with four lift points would consist of 16 jacks with a total lifting capacity of 32 million pounds. The budgetary costs projected by the DeLong Corp. are $50,000 for 500-ton units and $80,000 for 1000-ton units. Delivery time would be approximately six months. These jacks provide for fail-safe operation by the continuous engagement of one of the pins during the jacking operation.

The normal operating speed of the hydraulic jacks under load is 30 ft/hr., however, the system could be designed for operation at 60 or 80 ft. per hour. The jacks presently in use (see Figure 8-10, page 8-23), operate at 3200 psi and have a stroke of 20 to 22 inches.

Another heavy lifting device available commercially is the unit used to lift the platform of the LeTourneau Mobile Island Crane. (See Figure 8-11, page 8-24). This unit, called the Locomotive Drive, is rated at two million pounds lifting capacity. If each of the triangular leg were equipped with three locomotive drive units, a total lifting capability of 18 million pounds would be available.

These mobile islands can be built for operation in water up to 300 ft. deep. The LeTourneau cranes are available with capacities from 6 to 500 tons. One of the possible uses of such a platform would be the installation of the upper stages of launch vehicles. However, for this operation, it would be necessary for the platforms to be mobile. This mobility could be provided by crawler units.

3. TRANSPORTATION EQUIPMENT

In addition to serving as bases for high capacity gantry cranes, the Bucyrus Erie Crawlers are also capable of transporting completely assembled space vehicles.

A crawler unit for carrying an entire Saturn C-5 space vehicle has been concepted designed by the Bucyrus Erie Corp. This unit will be used

to transport the entire vehicle from the assembly facility to the launch facility. A typical configuration for such a vehicle is shown in Figure 8-12, page 8-25. In this case, a solid booster stage is shown being transported.

Some of the preliminary criteria are spelled out for this vehicle by Bucyrus Erie under NASA Contract 1024. The transporter will be designed to travel at a nominal speed of approximately 1 mph and to negotiate a curve of 500 ft. mean radius. It will climb and maintain a level platform up a 5% grade with a 300 ft. long vertical transition curve at either end. Accelerations and decelerations during propelling, starting and stopping will not exceed $\pm 2.58'/s^2$. The leveling system will be designed to maintain the platform level within zero degrees - 10 minutes. Positive steering will be provided to permit accurate lateral control of the transporter and D. C. adjustable voltage speed control will provide accurate positioning in the fore and aft direction. A means for locating the launcher to plus or minus 2 inches and holding it in place at the launch pad and assembly building is also proposed.

The weight of the vehicle to be carried is 4. 5 million pounds when fueled. A peak wind condition of 67. 6 knots at 400 feet both at the pad and during motion is assumed. It is further assumed that the tower could be subjected to 125 mph hurricane winds when anchored at the Vertical Assembly Building. A further assumption is that the space vehicle itself will be shielded during hurricane winds. The general dimensions and weights of the umbilical tower and its equipment, as supplied by the NASA, are as follows: height - 350 feet above level deck, base - 50 feet square, structural weight - 1. 3 million pounds, and equipment weight - 150, 000 pounds.

It is estimated that the platform structure will weight 3. 9 million pounds, exclusive of the 350, 000 pounds of miscellaneous equipment which will be housed in the platform structure.

The cylinder proposed for the leveling system has a 42-inch diameter bore and will have a maximum operating pressure of 2000 psi to resist a maximum cylinder loading of 2. 25 million pounds. A 7-foot piston extension is required to negotiate a 5% grade with a 140-foot long transporter.

For steering purposes, the front and repair of crawlers are tied together mechanically and each pair of crawlers is actuated by means of opposing, single-acting hydraulic cylinders of 25-inch diameter bore. Sufficient pump capacity is available to permit an angular change in direction of 10 degrees in one minute (more than that required to enter a 500-foot radius curve at 1 mph.)

A D. C. adjustable voltage control has been chosen for this system. This unit not only gives smooth acceleration characteristics but also permits plugging to give smooth deceleration. A spring-set air release brake will be provided on the motor to hold the transporter should an emergency stop be required for any reason.

It is estimated that the tractive effort required to move the transporter will be approximately 750,000 pounds. The additional tractive effort requirements for wind and 5% grade are 400,000 and 500,000 pounds respectively. The total tractive effort is, therefore, 1,650,000 pounds. It is proposed to design for 2.1 million pounds using eight 375 HP D. C. mill motors giving a total HP of 3000. Taking efficiency of gear trains and crawler belts into account, a speed of approximately 1 mph on level ground will result.

In order to generate power for propelling, a prime mover of 3500 hp is required to drive the four main D. C. generators. These may be powered in pairs by two 1750 hp diesel engines or gas turbines and will be accommodated on an auxiliary rubber-tired trailer.

Two possible concepts for the crawler transporter have been envisioned as follows: (1) to make the crawler and platform an integral unit (2) to make the crawler transporter a separate structure from the launcher platform. At present, the second method is favored.

A typical weight and cost breakdown for the second method as applied to a solid fueled vehicle was obtained from Bucyrus Erie Corp.:

Weight Breakdown.

Item	Weight Lbs.
Crawler Transporter	5,280,000
Launcher Platform Structural	3,650,000
Launcher Platform Miscellaneous	350,000
Umbilical Tower Structural	1,300,000
Umbilical Tower Miscellaneous	150,000
	10,730,000
Vehicle Weight	4,500,000
Total Weight:	15,230,000

Cost Breakdown

Umbilical Tower (Not included)	
Launcher Platform (Structural only)	
3, 650, 000 lbs. at 40 cents	$1, 460, 000
Contingencies 15%	219, 000
Engineering	72, 000
	$1, 751, 000
Independent Crawler Transporters	
Complete Unit	$4, 820, 000
Contingencies 5%	240, 000
Engineering Development Patterns, Tooling	490, 000
	$5, 550, 000

Bucyrus Erie Company has also concepted a vehicle for handling individual solid propellant motors in either the horizontal or vertical position. (See Figure 8-13, page 8-26). The general specifications for this particular vehicle are as follows:

Estimated Weight of Unit	2, 800, 000 lbs.
Approximate Payload	3, 500, 000 lbs.
Estimated speed on level ground	1 mph
Bearing Area	910 square ft.
Bearing Pressure (loaded)	6930 lbs/sq ft.
Bearing Pressure (unloaded)	3080 lbs/sq ft.
Turning Radius	500 ft.
Gradeability	5% Grade
Maximum travel of leveling jack	8 ft.

A concept for a rubber tired vehicle capable of serving as a mobile static test stand was supplied by Barnes and Reinecke Incorporated. (See Figure 8-14, page 8-27). No data as to load carrying capacities or design specifications were supplied.

4. COMPONENT HANDLING EQUIPMENT

Figure 8-15, page 8-28 presents examples of existing mobile component handling equipment. Concept A shows a Straddle Carrier manufactured by the Clark Equipment Co., generally used for the transportation of lumber. Its maximum capacity is 60, 000 pounds. The carrier is self-powered, has steerable front wheels and operates at road speeds up to 20 miles per hour. No information is available relative to the degree of modification required to

obtain the higher load capacities and the severe maneuverability necessary for segment handling devices required at the various solid motor facilities.

Figure 8-15B, page 8-28 shows a mobile crane or Travelift, manufactured by the Drott Co. Equipment similar to this is now used for solid motor handling at both United Technology Corp. and Aerojet General Corp. Although the Travelift at present is rated at 50 tons, it has demonstrated lifting capacities of 75 tons. Low hoisting speeds of 0.1 inch per second are used to protect sensitive loads against shock. The Travelift also has an auxiliary hoist of 8 tons capacity. Steerable rubber-tired wheels provide limited maneuverability. The Drott Company was contacted to obtain their feeling on possible modifications of the Travelift to increase its load carrying capacities to greater than 300,000 pounds. They stated however, that an engineering design study would be required to supply this data.

Figure 8-15C, page 8-28 was supplied by the Army's Transportation and Research Command, Ft. Eustis, Va. The picture represents one of two existing Landing Craft Retrievers. This particular model, the LCR Mark II, has a 70 ton capacity. The device has very limited maneuverability but can operate in water depths up to 8 feet. The other existing unit has a capacity of 100 tons. Both units are powered by 2 diesel engines and can be assembled in the field.

Two additional examples of component handling equipment are shown in Figures 8-16 and 8-17, pages 8-29 and 8-30. Figure 8-16 shows a 110 ton mobile refueling crane which was designed by the Crane and Hoist Division of the Manning Maxwell and Moore Co. to operate on the hangar deck of the atomic powered aircraft carrier Enterprise. The crane is self propelled. It rides on 16 solid rubber tires and is capable of maneuvering in twelve directions. This device is capable of positioning a load to within 1/8 inch. No information on uprating of load characteristics or costs was supplied.

Figure 8-17, page 8-30 is the other example of a mobile component handling device. This unit is called a Transtainer and is manufactured by the Pacific Coast Engineering Co. At the present time the largest of these units has a capacity of 40 tons with a hoist steed of 10 FPM. From the view shown, one can easily imagine this unit being used to handle segments of solid propellant rocket motors. A continuous power steering unit provides effortless control and a minimum turning radius. The sturdy, equalized structure is capable of withstanding the shock loads of rough terrain operation. The large 100 pound pressure tires enable operation on any heavy trucking pavement without damage to the roadway. Operating speed is three miles per hour.

Figure 8-18, page 8-31 is a concept for a self propelled segment handling dolly supplied by Caterpillar Tractor Co. of Peoria, Illinois. The Dolly shown is for a 200,000 lb. load. By increasing tire size, and the number and arrangement of the wheels, increases in load carrying capacity can be realized. Caterpillar Tractor Co. feels that the best method of propulsion and steering would be electric. This would allow 360° steering-crab steering, regular automatic steering or the ability to turn the wheels 90° to the longitudinal axis.

Figure 8-19, page 8-32 supplied by Press Ray Corp., describes the principle and describes the application of their Pneuma Grip to solid motor component handling. The principle has been used effectively to handle nose cones, re-entry vehicles, engines (both liquid and solid), nozzles and other component assemblies. Lifting units with capacities up to 560,000 lbs. have been designed. The prime advantage of this method of lifting is the equal distribution of load. No cost data for this equipment was supplied.

5. MISCELLANEOUS A. G. E.

Figure 8-20, page 8-33 supplied by the Neptune Meter Co., shows a typical thrust stand with associated calibration equipment and remote controls. A stand similar to the one shown, with a capability of 750,000 lbs., was supplied to the United Technology Corporation for testing of solid motors. Design data and order of magnitude costs for thrust stands capable of sustaining loads up to 10 million pounds was not available.

Figure 8-21, page 8-34 presents typical examples of available equipment applicable to the many operations performed at solid motor manufacturing, static test and launch facilities. These mobile units are manufactured by the Ballymore Co. A variety of models of the mobile access lift are available with maximum reaches between 19 and 42 ft., working heights between 12 and 40 ft., platform travel between 7 and 25 ft., and elevating times between 45 seconds and 4 minutes. The costs of the mobile access lifts range between 1100 and 2300 dollars. The hydraulic work platforms shown come in a variety of models with load capacities between 800 and 1600 lbs. and elevations between 10 and 17 ft. The prices for these units range between 1400 and 2600 dollars.

FOR DISCUSSION REFER TO PAGE 8-1

TABLE 8-1

HEAVY LIFTING EQUIPMENT - 50 - 500 TON CAPACITIES

LIFTING CAPACITY SHORT TONS	APPLICABLE LIFTING EQUIPMENT	SOURCE
50	GANTRY AND SEMI-GANTRY CRANES HAMMERHEAD CRANES OVERHEAD TRAVELING CRANE PORTAL AND TOWER CRANES LOCOMOTIVE AND CRAWLER CRANES TRUCK CRANES FLOATING CRANES A-FRAME AND STIFFLEG DERRICKS GUY DERRICKS	REFERENCE: DESIGN MANUAL "WEIGHT HANDLING EQUIPMENT AND SERVICE CRAFT" NAVDOCKS DM-38 (DEPARTMENT OF THE NAVY) 19 FEBRUARY 1962.
	HYDRAULIC AND PNEUMATIC JACKS	SURVEY OF AGE MANUFACTURERS
100	GANTRY AND SEMI-GANTRY CRANES HAMMERHEAD CRANES OVERHEAD TRAVELING CRANES LOCOMOTIVE AND CRAWLER CRANES FLOATING CRANES A-FRAME AND STIFFLEG DERRICKS	NAVDOCKS DM-38
	HYDRAULIC AND PNEUMATIC JACKS	SURVEY OF AGE MANUFACTURERS
250	GANTRY AND SEMI-GANTRY CRANES HAMMERHEAD CRANES OVERHEAD TRAVELING CRANES LOCOMOTIVE CRANES FLOATING CRANES A-FRAME AND STIFFLEG DERRICKS	NAVDOCKS DM-38
	HYDRAULIC AND PNEUMATIC JACKS	SURVEY OF AGE MANUFACTURERS
500	OVERHEAD TRAVELING CRANES	NAVDOCKS DM-38
	A-FRAME AND STIFFLEG DERRICKS	NAVDOCKS DM-38
	FLOATING DERRICK	LONG BEACH NAVAL STATION, CAL.
	GANTRY CRANE (CONCEPTS)	BUCYRUS-ERIE CO., MORGAN ENG.
	PNEUMATIC JACKS	DELONG CORP.
	HYDRAULIC JACKS	DELONG CORP., ROGERS HYDRAULIC.
	LOCOMOTIVE DRIVE DEVICES	R. G. LETOURNEAU INC.

FOR DISCUSSION REFER TO PAGE 8-1

TABLE 8-2

HEAVY LIFTING EQUIPMENT - 1000 - 16000 TON CAPACITIES

LIFTING CAPACITY SHORT TONS	APPLICABLE LIFTING EQUIPMENT	SOURCE
1,000	GANTRY CRANE (CONCEPTS) HYDRAULIC JACKS LOCOMOTIVE DRIVE DEVICES	BUCYRUS ERIE CO., ALLIANCE MACHINE CO., MORGAN ENGINEERING CO. THE DELONG CORP. R. G. LETOURNEAU INC.
5,000	GANTRY CRANE (CONCEPTS) HYDRAULIC JACK COMBINATIONS COMBINATIONS OF LOCOMOTIVE DRIVE LIFTING DEVICES	ALLIANCE MACHINE CO. THE DELONG CORP. R. G. LETOURNEAU INC.
9,000	HYDRAULIC JACK COMBINATIONS COMBINATIONS OF LOCOMOTIVE DRIVE LIFTING DEVICES	THE DELONG CORP. R. G. LETOURNEAU INC.
16,000	HYDRAULIC JACK COMBINATIONS	THE DELONG CORP.

FOR DISCUSSION REFER TO PAGE 8-1

TABLE 8-3

GENERAL CHARACTERISTICS OF HIGH CAPACITY CRANES

	ITEM	GANTRY AND SEMI-GANTRY	HAMMERHEAD	OVERHEAD TRAVELING	PORTAL	TOWER
1	Reaches	Spans to 400-600 ft (light loads)	Over 200 ft feasible	Span 200 ft or more feasible	Over 200 ft practical	Somewhat less than portals
2	Hook Capacities	10 to 250 tons existing, Larger capacities feasible.	5 to 350 tons existing - larger feasible	1 to 562.5 gross tons existing - larger feasible	3 to 75 tons existing - larger capacities feasible	Usually less than portals, but large capacities feasible
3	Moment Capacities	Not applicable	40,000 ft-tons existing - larger feasible	Not applicable	8,300 ft-tons existing - larger capacities feasible	Somewhat less than portals
4	Heights of Lifts	Unlimited, except by height of structure	135 ft on main hook 217 ft on 15-ton hook existing - higher practical	Unlimited, except by height of runway structure	85 to 100 ft on main hook, 220 ft on 5-ton hook existing - higher practical	No definite limits
5	Speeds of Motions	As desired, except travel slow	As desired, except travel slow	As desired, including very fast	As desired	As desired, except travel must be slow
6	Fineness of Control	As desired	As desired	Excellent	As desired	As desired
7	Stability	Breaking strength	Good, when special pre-cautions are taken in design	Breaking strength	Excellent	Good, when very special precautions are taken in design
8	Safety in Operation	Excellent	Excellent	Excellent	Excellent	Good
9	Ease of Operation	Good - direct (noncircular) motions aid in spotting	Good - level traversing aids in spotting	Excellent - direct (noncircular) motions aid in spotting	Good	Good
10	Overall Quality Practical	Highest	Highest	Highest	Highest	Highest
11	Reliability	Good to excellent	Good to excellent	Excellent	Good to excellent	Good to excellent
12	Area Coverage	Good, but limited by special straight track	Fair, but limited to straight track or with gentle curves - large sizes fixed	Limited by runway structure	Good, but limited by special track required	Fair - limited to straight track or track with gentle curves
13	Mobility Range	Limited by Special track	Limited by Special track	Limited by runway structure	Limited by Special track	Limited
14	Portability	Not portable	Not portable	Small sizes only are portable	Not portable	Not portable
15	Operator's Visibility	Excellent	Excellent	Excellent	Good to excellent	Excellent
16	Effect on Pavement	Track undesirable	Track undesirable	Not applicable	Track undesirable	Track undesirable
17	Interference With Adjacent Operations	Moderate (track)	Considerable	Slight, indoors - considerable, outdoors	Considerable	Considerable
18	Collateral Costs	High (track and power supply)	High (track)	High (runway, building height)	High (track)	High (track)
19	Operating Costs	Low	Medium	Very low	Medium	Medium
20	Size of Crew	2 to 3	3	1	3	3

FOR DISCUSSION REFER TO PAGE 8-1

TABLE 8-4

GENERAL CHARACTERISTICS OF MOBILE CRANES

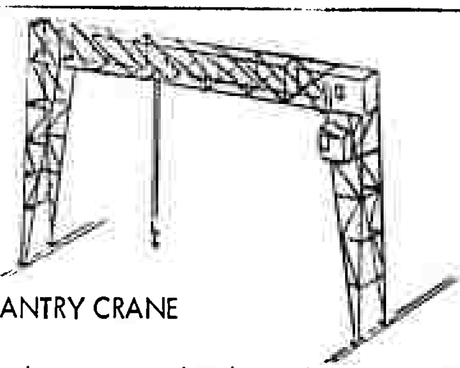
	ITEM	LOCOMOTIVE	CRAWLER	MOTOR-TRUCK	FLOATING
1	Reaches	Up to 100 ft (50 to 60 ft usual)	Up to 100 ft, except very special cranes - 30 to 60 ft usual	Up to 100 ft, 30 to 60 ft usual	Over 200 ft feasible
2	Hook Capacities	1/2 to 250 tons - smallest at long reaches, largest under special conditions	1/2 to 100 tons larger feasible	1/2 to 80 tons	350 gross tons existing - larger feasible
3	Moment Capacities	3000 ft-tons	4000 ft tons larger feasible	4000 ft-tons	40,000 ft-tons existing - larger feasible
4	Heights of Lifts	40 to 80 ft	85 to 95 ft	85 to 95 ft	170 ft on main hook, 300 ft on 5-ton hook existing - as high as necessary
5	Speeds of Motions	Fast	Fast, except travel very slow	Fast, fastest travel	Good, except travel (propulsion) slow
6	Fineness of Control	Rough to fair	Rough to fair	Rough to fair	As desired
7	Stability	Very low unless blocked	Low (fair)	Very low	Excellent
8	Safety in Operation	Poor	Poor	Poor	Excellent
9	Ease of Operation	Fair	Poor to fair	Poor to fair	Good
10	Overall Quality Practical	Good	Good	Good	Highest
11	Reliability	Excellent	Fair to good	Fair to good	Good to Excellent
12	Area Coverage	Good, but limited to railway track	Excellent (best)	Excellent	Excellent, unlimited on protected water
13	Mobility Range	Limited to track	Generally excellent, but limited in operation to areas of high ultimate bearing power	As for crawlers (best)	Excellent, unlimited on protected water
14	Portability	Excellent on railway track	Fair to excellent	Excellent via highway	Excellent (by tow)
15	Operator's Visibility	Fair	Fair	Fair	Good to excellent
16	Effect on Pavement	None resulting from crane	Very poor (destructive)	Minimum if strongly supported	Not applicable
17	Interference with Adjacent Operations	Minimum	Slight	Slight	Slight
18	Collateral Costs	Slight (local track supports)	Normal use Minimum - abnormal use, high (special supports, and so on)	Normal use minimum - abnormal use, high (special supports, and so on)	Medium (berthing)
19	Operating Costs	Medium	Medium	Medium to high	High
20	Size of Crew	2	1 to 2	2	5 to 40

FOR DISCUSSION REFER TO PAGE 8-1

TABLE 8-5

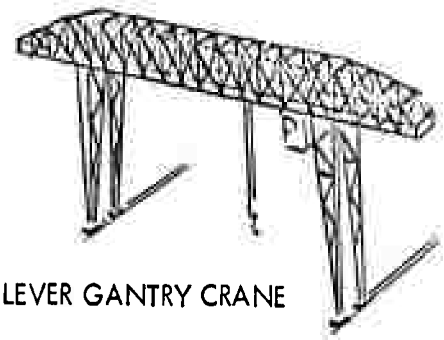
GENERAL CHARACTERISTICS OF DERRICKS

	ITEM	A-FRAME AND STIFFLEG	GUY	GIN-POLE
1	Reaches	Commonly 50 to 100 ft 250 ft has been built	50 to 130 ft	Short in relation to height
2	Hook Capacities	1 to 800 tons existing larger feasible	5 to 50 tons the latter large	Usually small, up to 10 tons
3	Moment Capacities	Up to 20,000 ft-tons existing - larger feasible	5,000 ft-tons feasible	Not applicable
4	Heights of Lifts	220 ft for derrick alone has been built with towers or framework, indefinite	80 to 100 ft for derrick alone with towers or on framework, indefinite	Over 100 ft has been used, derrick alone
5	Speeds of Motion	Fast, except rotate often, very slowly	Fast, except rotate often, slowly	Slow
6	Fineness of Control	Generally poor	Generally poor	Rough, if powered
7	Stability	Good	Breaking strength	Good
8	Safety in Operation	Poor	Poor	Poor
9	Ease of Operation	Poor	Poor	Poor
10	Practicable Overall Quality	Fair	Fair	Fair
11	Reliability	Fair to good	Fair to good	Good
12	Area Coverage	Poor (usually fixed)	Poor (always fixed)	Minimum
13	Mobility Range	None (usually fixed)	None (always fixed)	None (fixed)
14	Portability	Excellent	Excellent	Maximum
15	Operator's Visibility	Poor to fair	Poor to fair	Poor to fair
16	Effect on Pavement	Not applicable	Not applicable	Not applicable
17	Interference with Adjacent Operations	Considerable	Considerable	Medium
18	Collateral Costs	Low	Low	Low
19	Operating Costs	High	High	High
20	Size of Crew	1 to 3	1 to 1	1



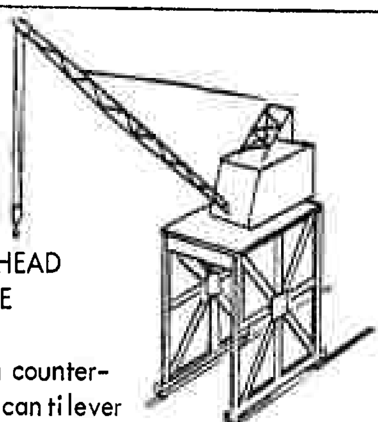
GANTRY CRANE

Similar to an overhead traveling crane, except that the bridge for carrying the trolley or trolleys is rigidly supported on two or more movable legs running on fixed rails or other runways.



CANTILEVER GANTRY CRANE

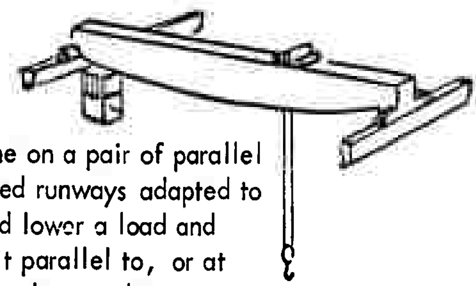
The bridge girders or trusses extend transversely beyond the crane runway on one or both sides, with the runways either on the ground or elevated.



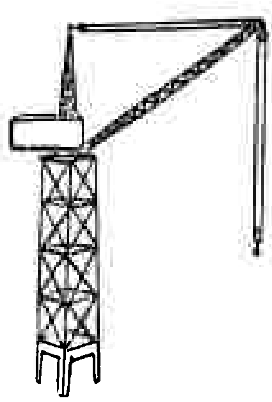
HAMMERHEAD CRANE

A rotating counter-balanced cantilever equipped crane with one or more trolleys and supported by a pivot or turntable on a traveling or fixed tower

OVERHEAD TRAVELING CRANE

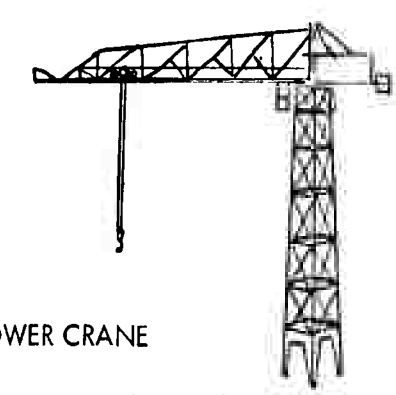


A crane on a pair of parallel elevated runways adapted to lift and lower a load and carry it parallel to, or at right angles to, the runways. It consists of one or more trolleys operating on top or bottom of a bridge, which in turn consists of one or more girders or trusses mounted on trucks operating on the elevated runways. Operation is limited to the area between.



PORTAL CRANE

A fixed or mobile gantry crane, without trolley motion, it has a boom attached to a revolving crane mounted on a gantry, with a boom capable of being raised or lowered at its head.



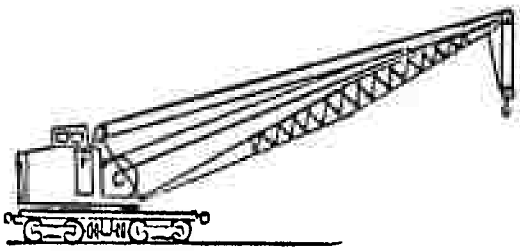
TOWER CRANE

A portal crane, with or without an opening between the legs of its supporting structure, mounted on a fixed or mobile towerlike gantry and adapted to hoist and swing loads over high obstructions. The revolving crane may be supported on the tower by a revolving mast or by a turntable

FOR DISCUSSION REFER TO PAGE 8-1

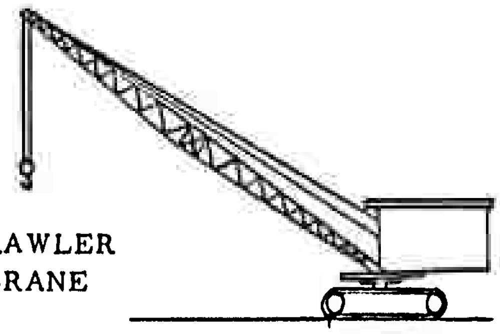
FIGURE 8-1
HIGH CAPACITY CRANES

FOR DISCUSSION REFER TO PAGE 8-1



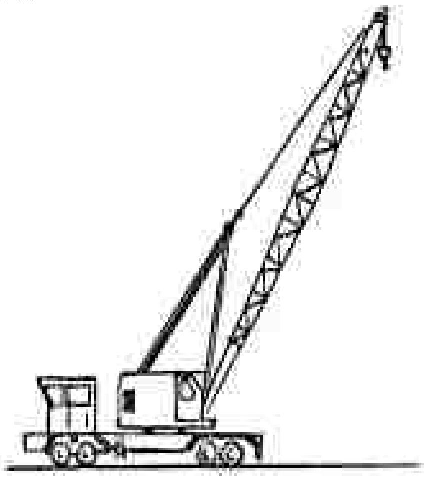
LOCOMOTIVE CRANE

Consists of a self-propelled car operated on a railroad track, upon which is mounted a rotating body supporting the power-operated mechanisms, together with a boom capable of being raised or lowered at its head (outer end), from which end is led a wire rope for raising and lowering a load.



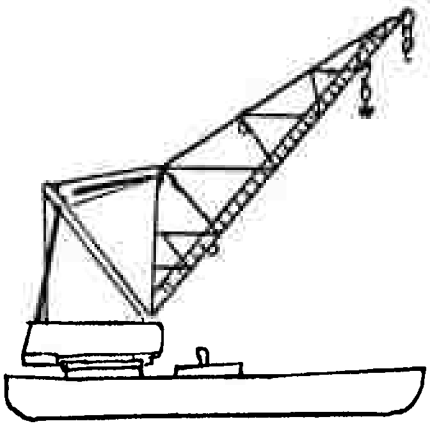
CRAWLER CRANE

A type of locomotive crane, mounted on a tractor frame instead of a railroad car, that utilizes tractor or track-laying belts or treads for locomotion in any direction.



MOTOR-TRUCK CRANE

A type of locomotive crane mounted on a motor-truck frame on rubber-tired chassis.



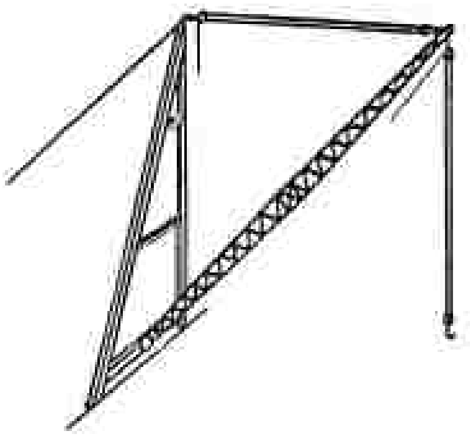
FLOATING CRANE

A crane with an integral base consisting of a pontoon, barge, or hull. It may be of the portal, gantry, or tower type.

FIGURE 8-2
MOBILE CRANES

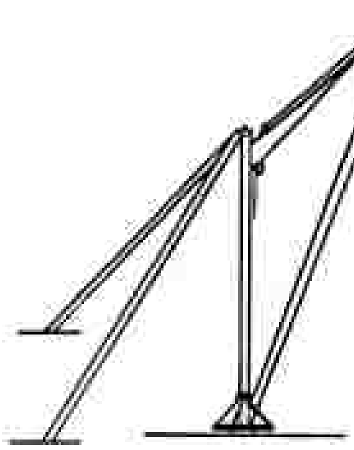
FOR DISCUSSION REFER TO PAGE 8-1

A-FRAME DERRICK



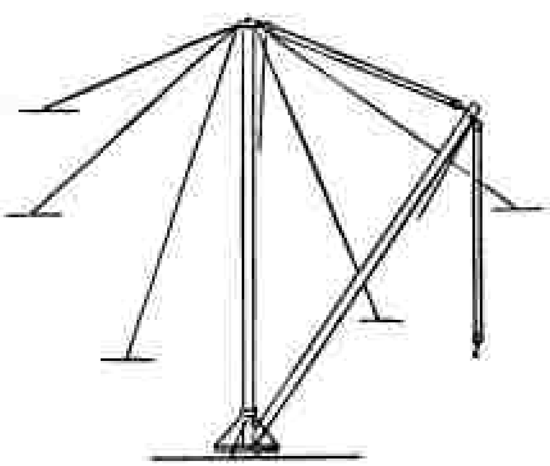
The boom is hinged from a cross member between the bottom ends of two upright members spread apart at the lower ends and united at the top, the upper end of the boom being secured to the upper junction of the side members, and the side members braced or guyed from the junction point.

STIFFLEG DERRICK



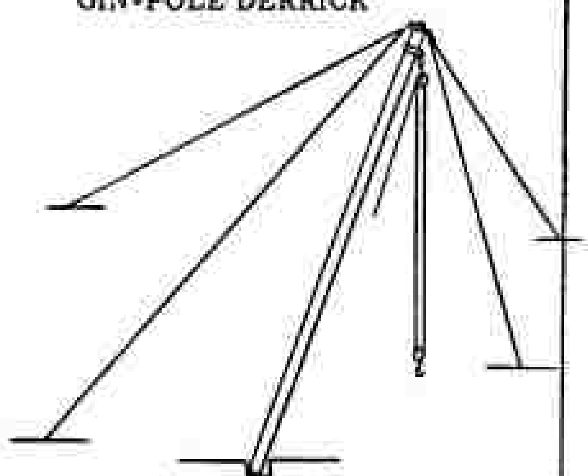
Similar to a guy derrick except that the mast is supported or held in place by two or more stiff members capable of resisting both tensile and compressive forces. Sills are generally provided to connect the lower ends of the two stifflegs to the foot of the mast.

GUY DERRICK



A fixed derrick consisting of a mast, capable of being rotated, that is supported in a vertical position by three or more guys, and a boom with its bottom end hinged or pivoted to move in a vertical plane; lines between the head of the mast and the head of the boom are used for raising and lowering the boom, and lines from the head of the boom for raising or lowering the load.

GIN-POLE DERRICK



One consisting only of a mast, with guys from its top arranged to permit leaning the mast in any direction, the load being raised or lowered by ropes leading through sheaves or blocks at the top of the mast.

FIGURE 8-3
DERRICKS

FOR DISCUSSION REFER TO PAGE 8-1

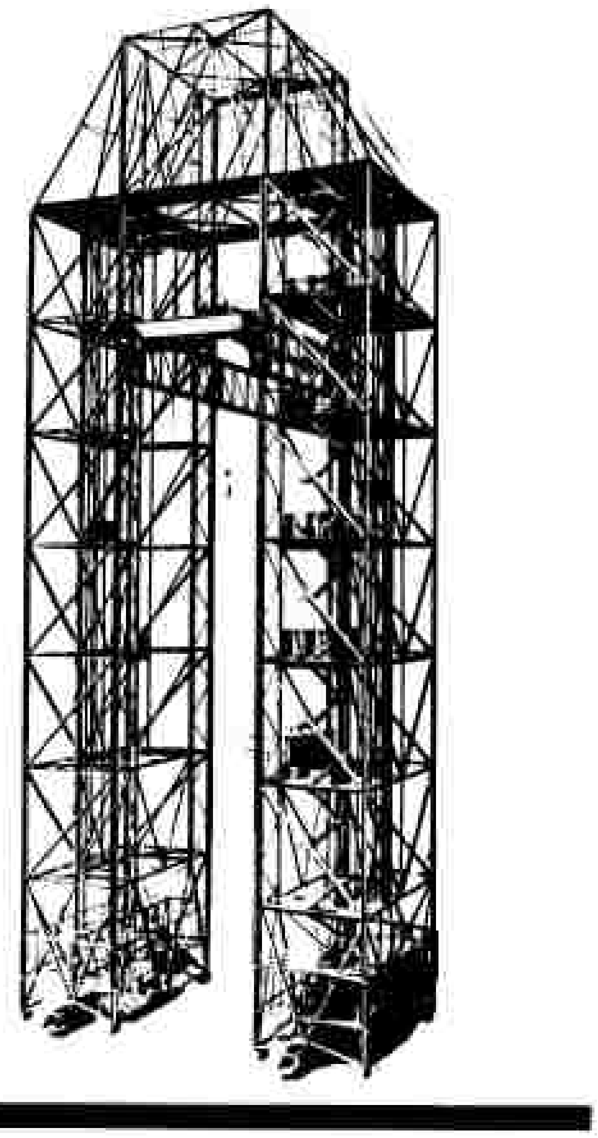


FIGURE 8-4

MISSILE SERVICE TOWER
U. S. CORPS OF ENGINEERS
(SUPPLIED BY KAISER INDUSTRIES CORP,)

FOR DISCUSSION REFER TO PAGE 8-2

FIGURE 8-5
WORLD'S LARGEST STRIPPING SHOVEL
(SUPPLIED BY BUCYRUS - ERIE CORP.)

FOR DISCUSSION REFER TO PAGE 8-2

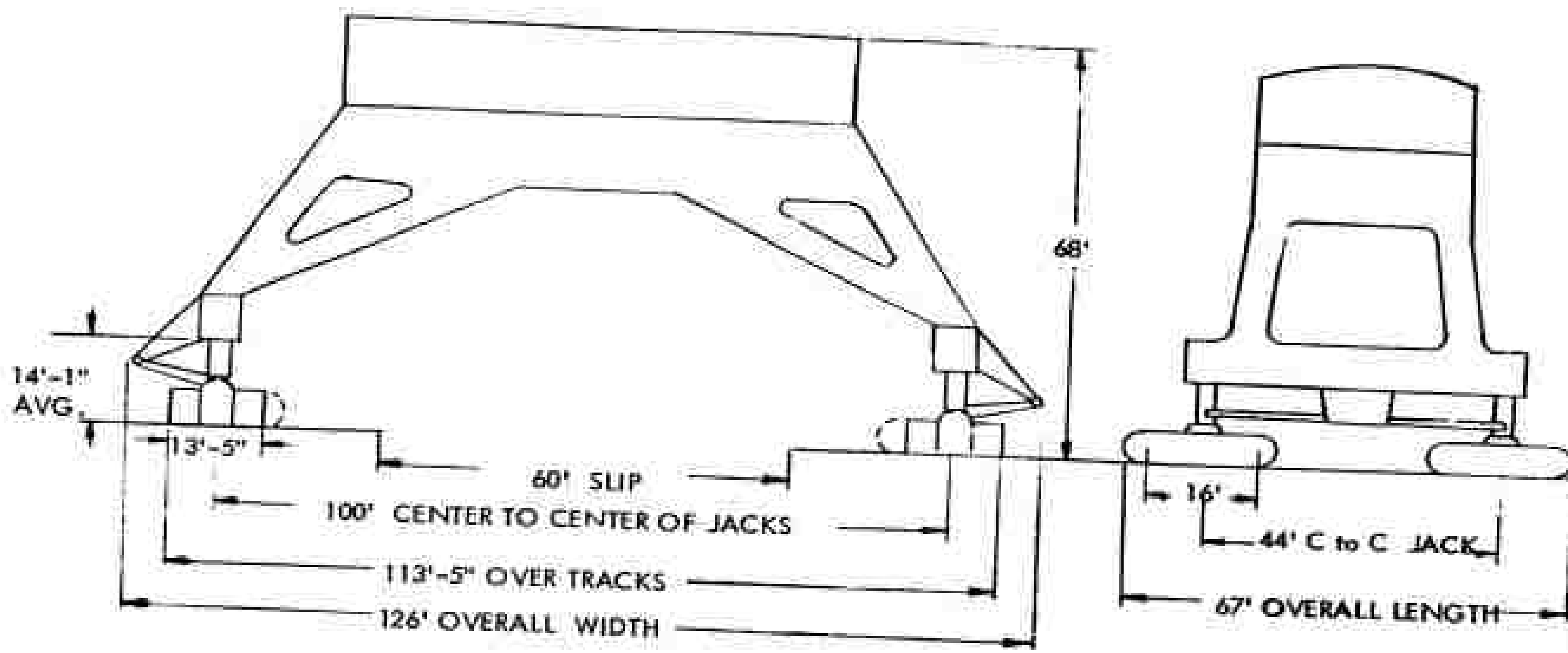


FIGURE 8-6
800 TON CRAWLER MOUNTED GANTRY CRANE
(SUPPLIED BY BUCYRUS ERIE CORP.)

FOR DISCUSSION REFER TO PAGE 8-2

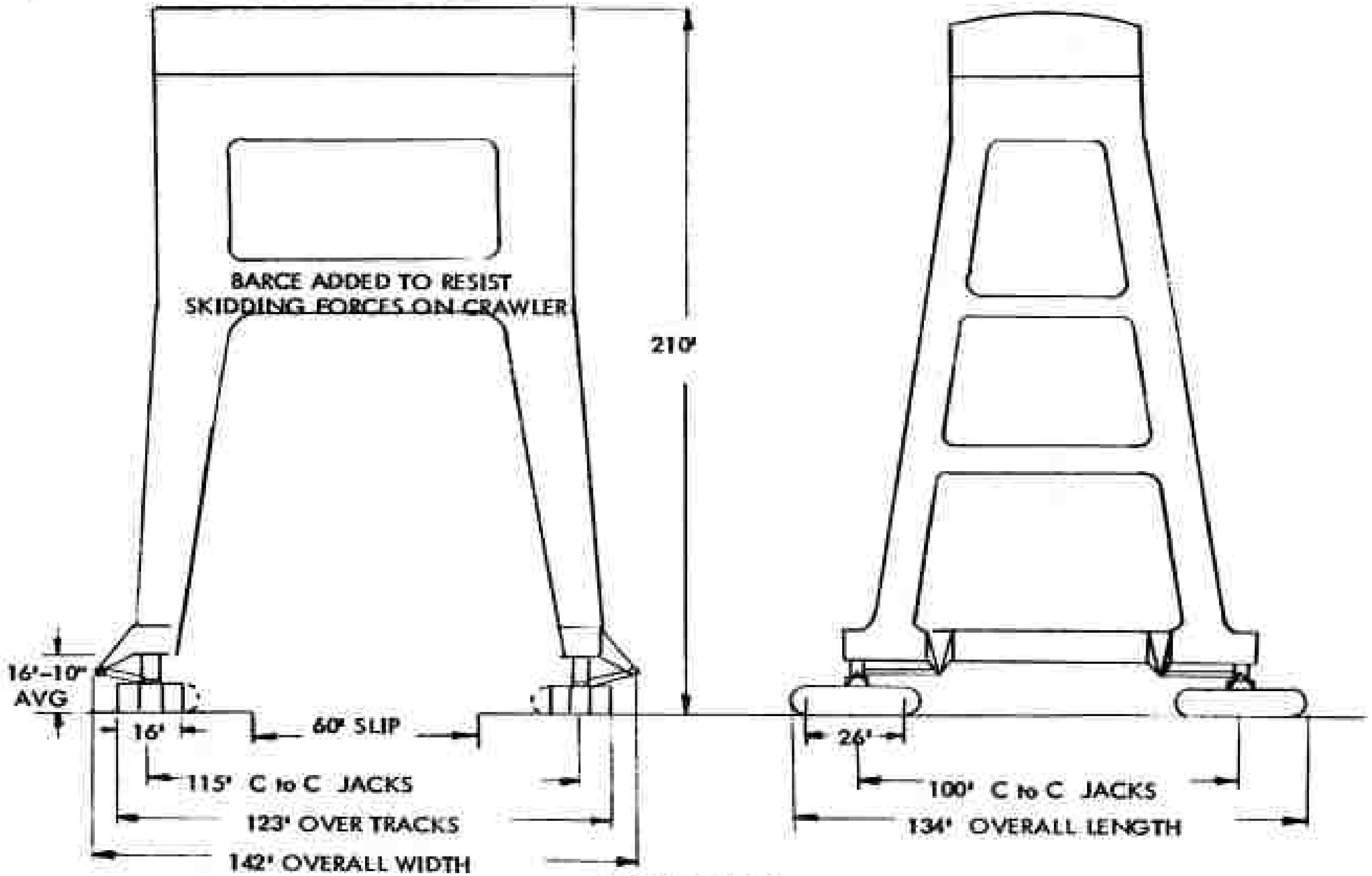


FIGURE 8-7
1,600 TON CRAWLER MOUNTED GANTRY CRANE
(SUPPLIED BY BUCYRUS ERIE CORP.)

FOR DISCUSSION REFER TO PAGE 8-2

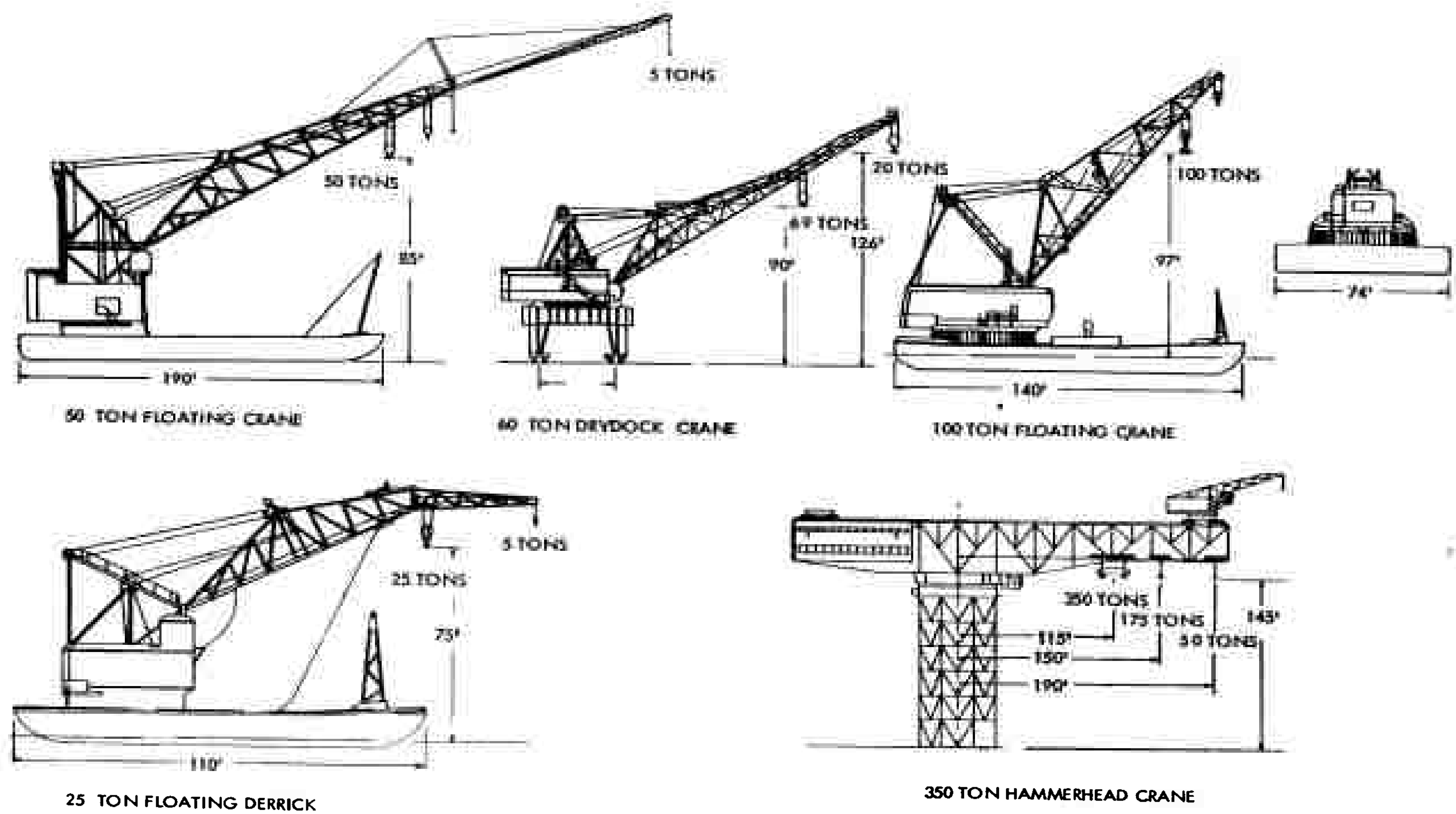
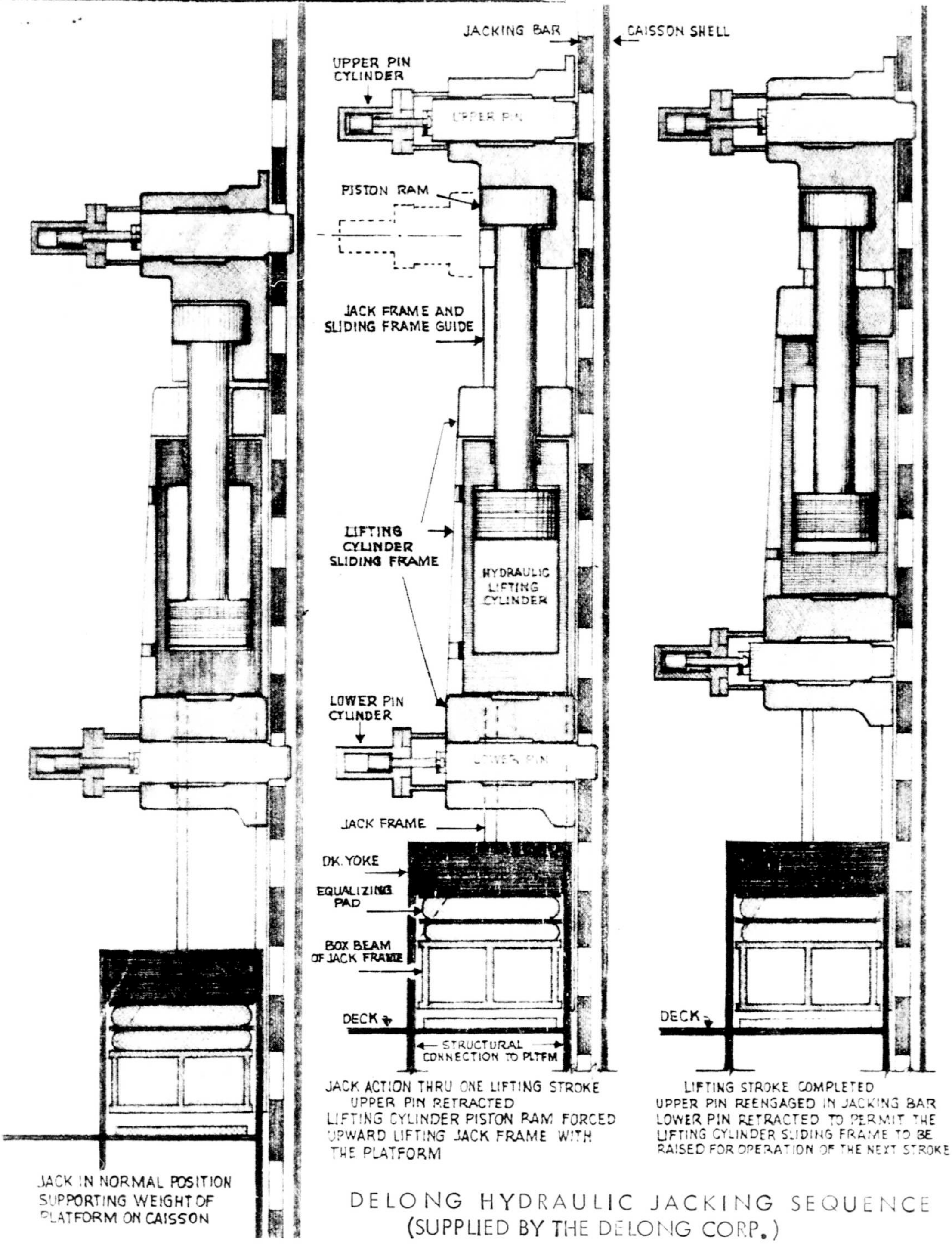


FIGURE 8-8
FLOATING CRANES
(SUPPLIED BY NEW YORK NAVAL SHIPYARD)

FOR DISCUSSION REFER TO PAGE 8-3



DELONG HYDRAULIC JACKING SEQUENCE
(SUPPLIED BY THE DELONG CORP.)

FIGURE 8-9

FOR DISCUSSION REFER TO PAGE 8-3

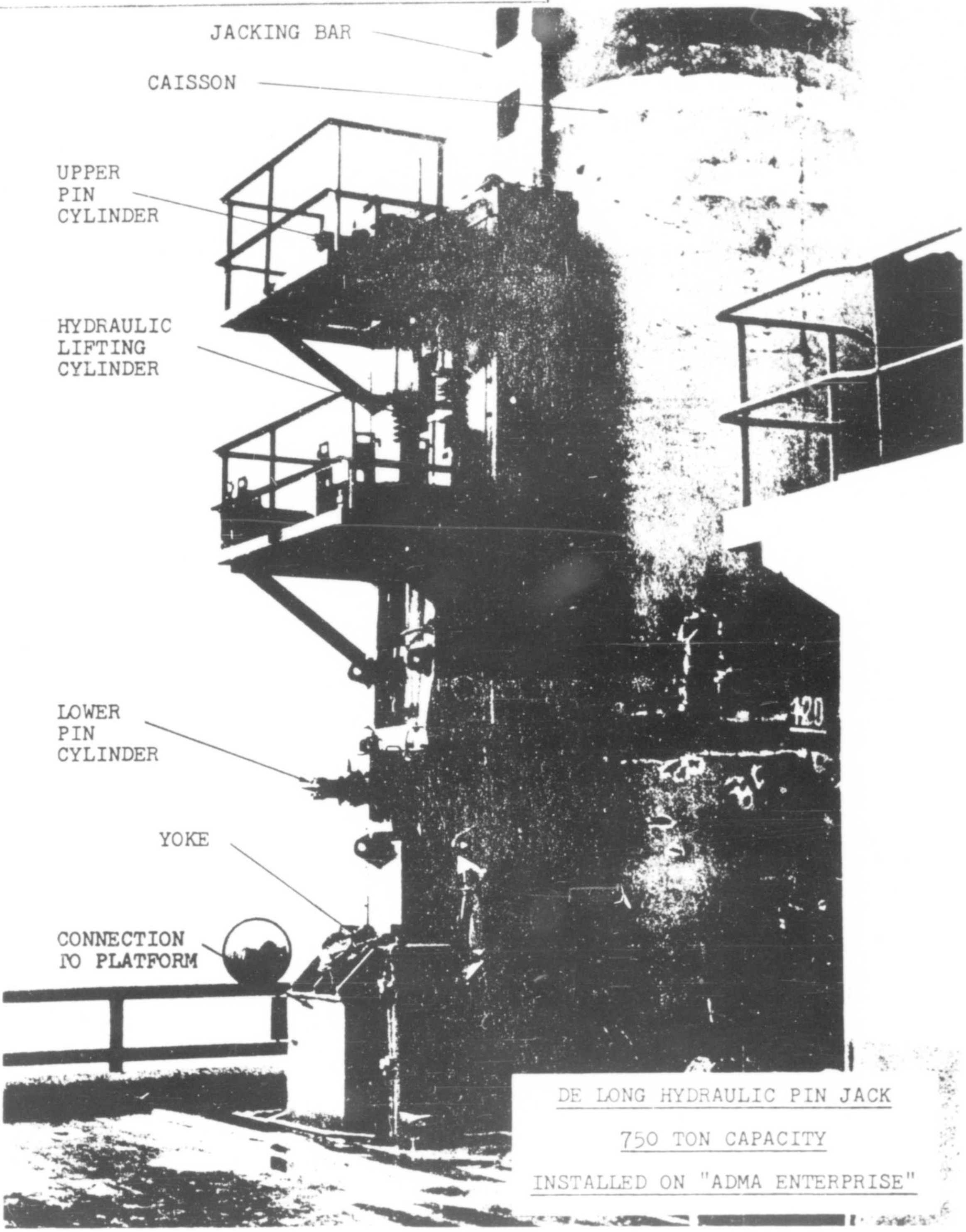
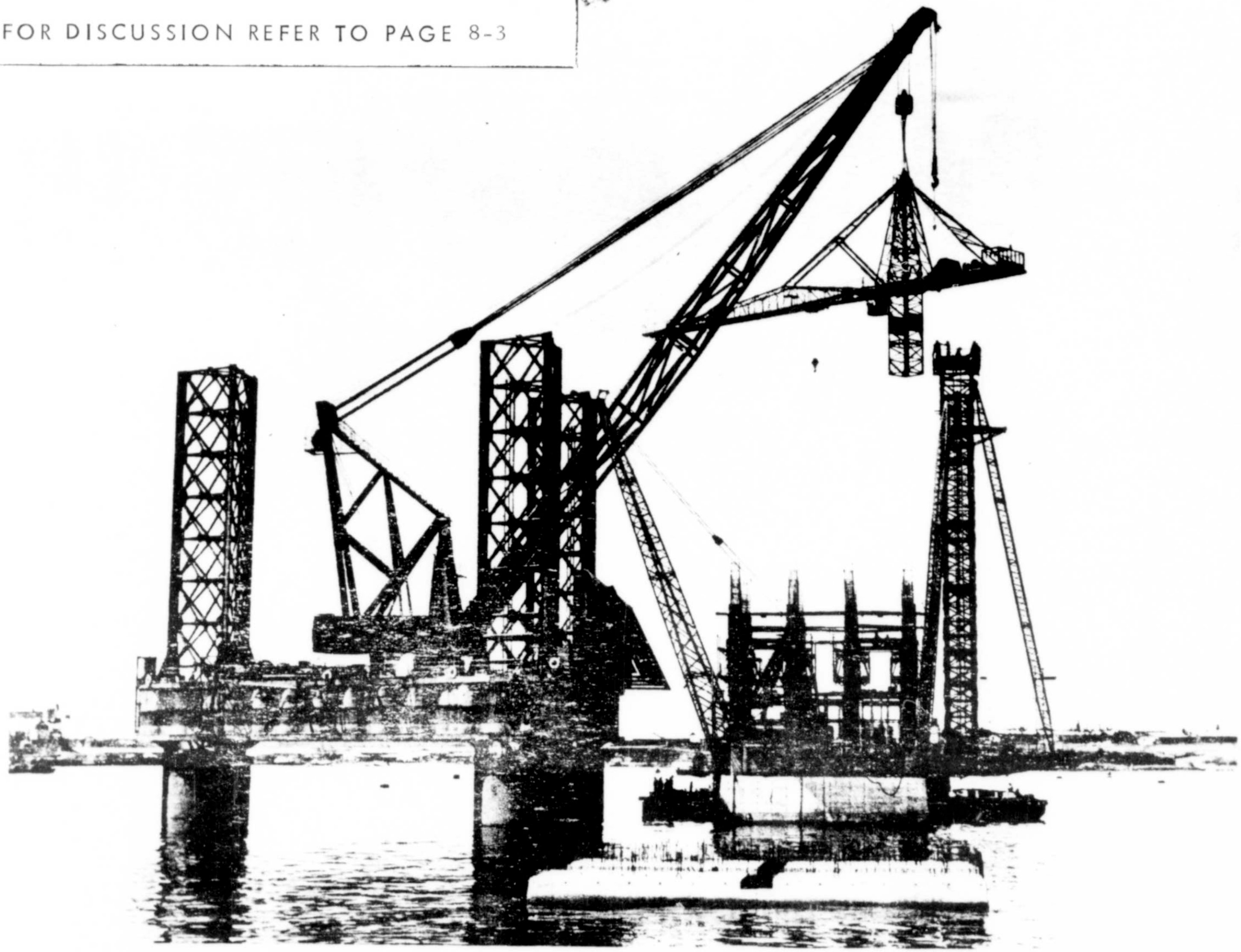


FIGURE 8-10

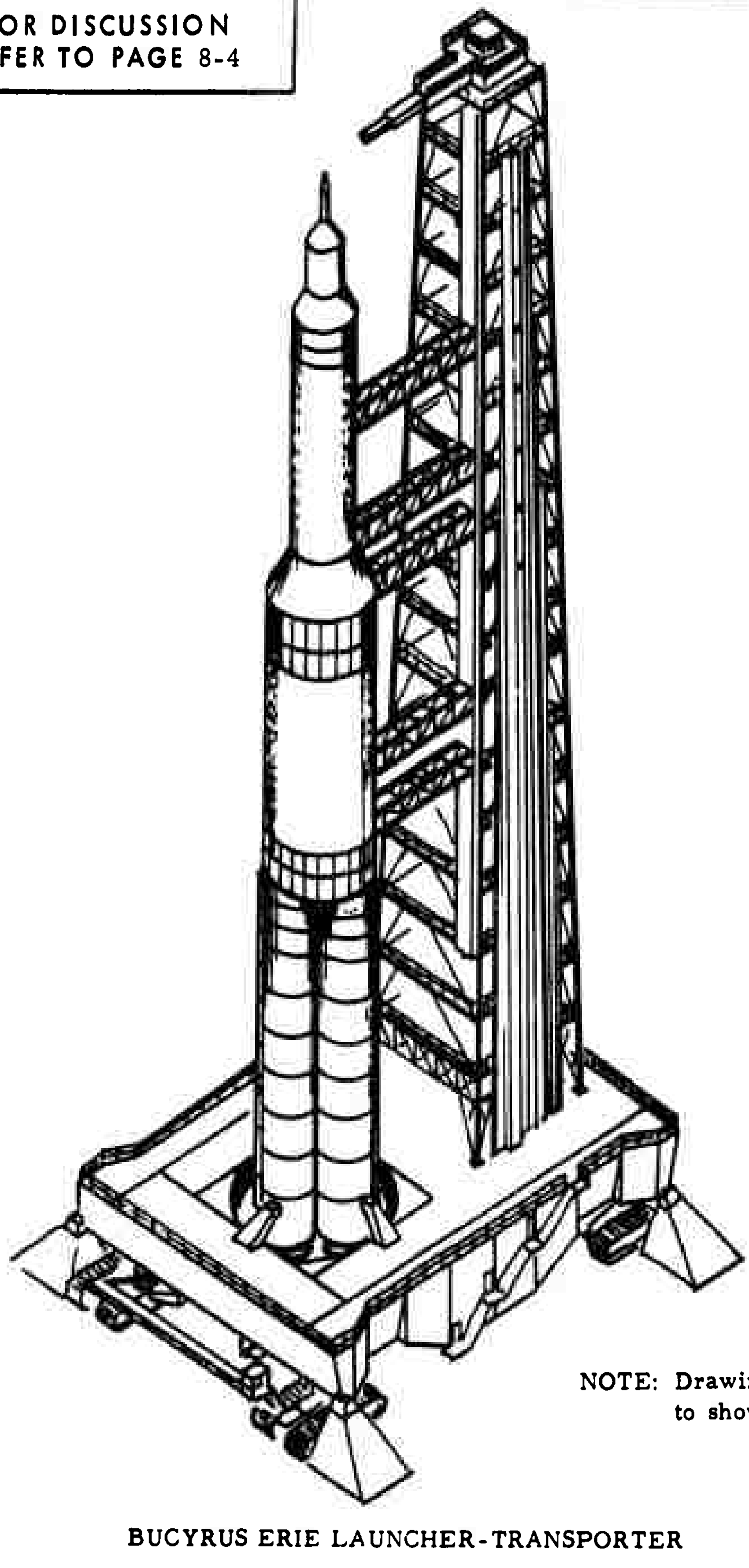
FOR DISCUSSION REFER TO PAGE 8-3



LE TOURNEAU MOBILE ISLAND CRANE

FIGURE 8-11

FOR DISCUSSION
REFER TO PAGE 8-4



NOTE: Drawing modified by AMF to show Solid Motor Booster

BUCYRUS ERIE LAUNCHER-TRANSPORTER

FIGURE 8-12

FOR DISCUSSION REFER TO PAGE 8-6

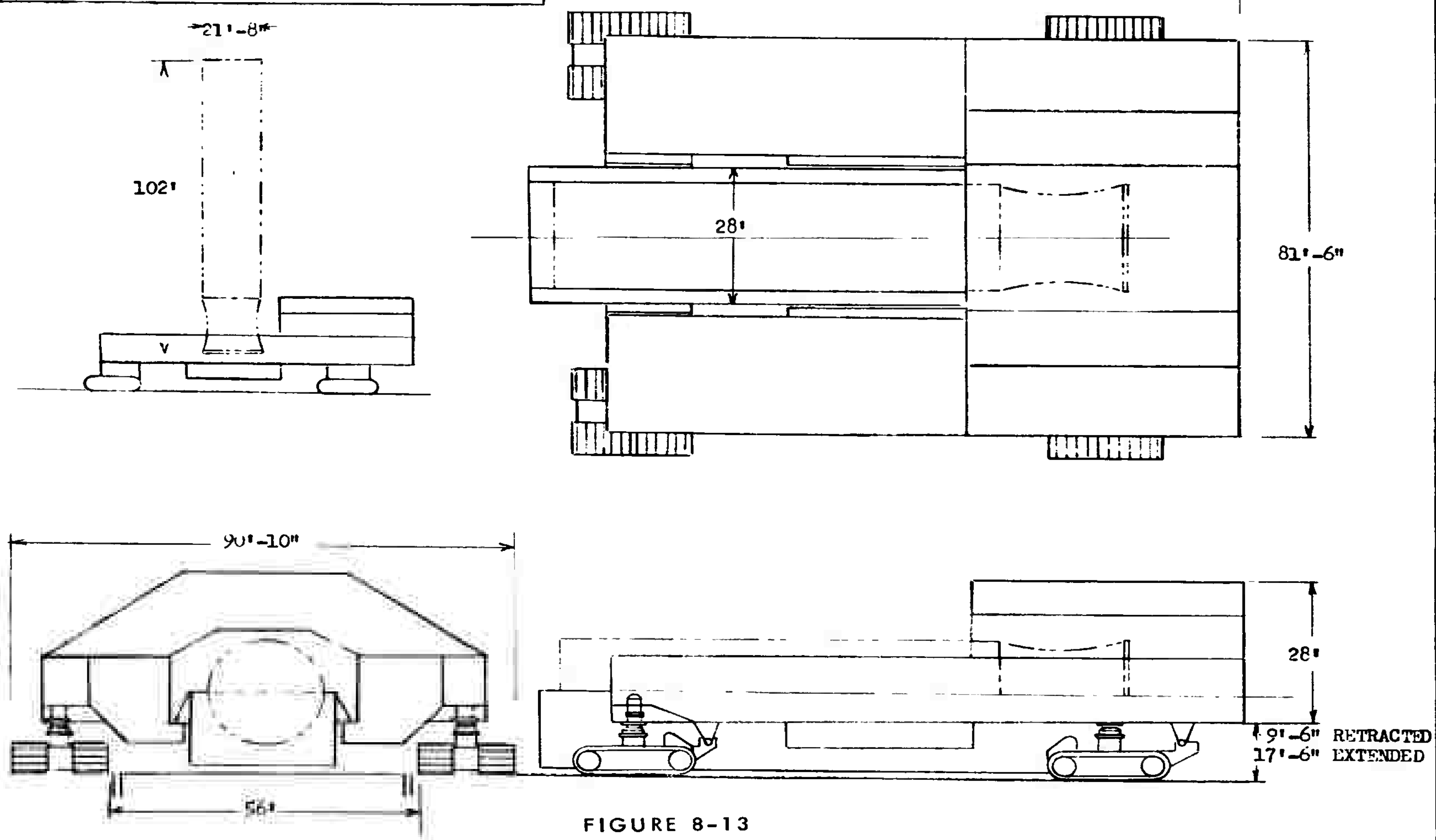


FIGURE 8-13
SOLID MOTOR TRANSPORTER
(SUPPLIED BY BUCYRUS - ERIE CORP.)

FOR DISCUSSION REFER TO PAGE 8-6

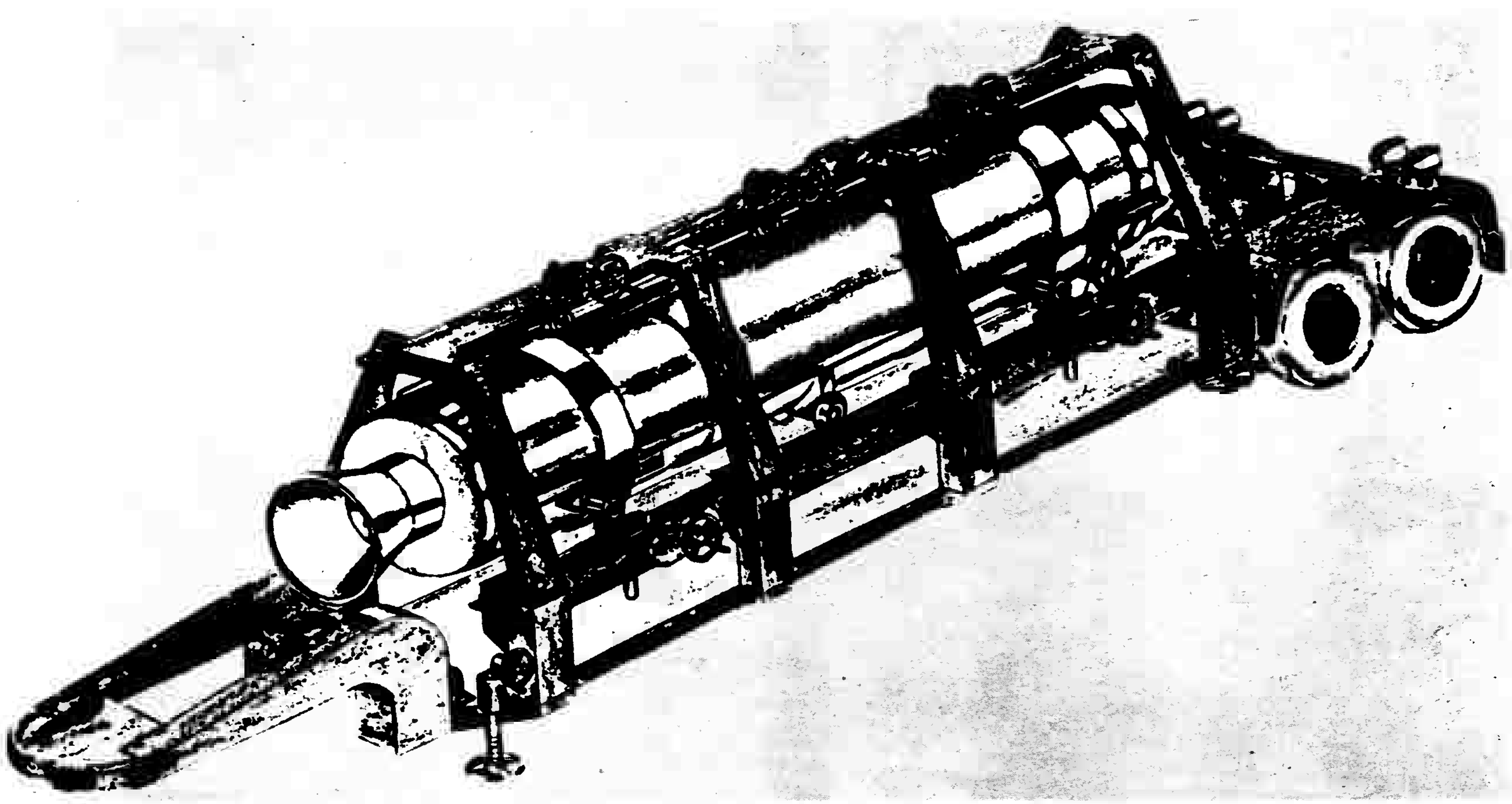
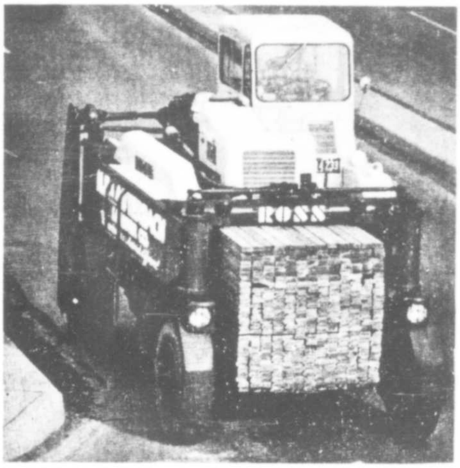
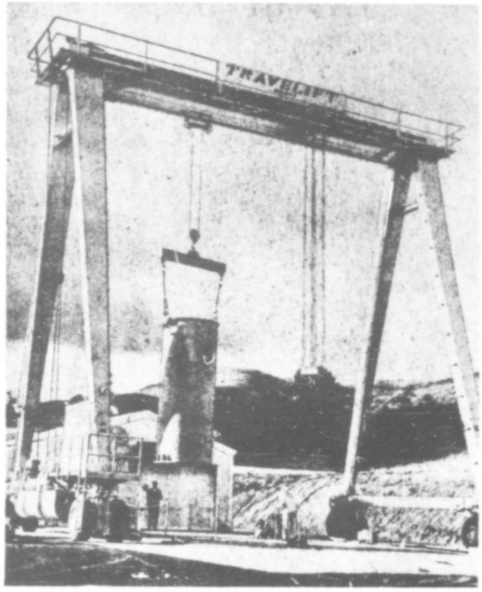


FIGURE 8-14
MOBILE TEST STAND
(SUPPLIED BY BARNES AND REINECKE INC.)

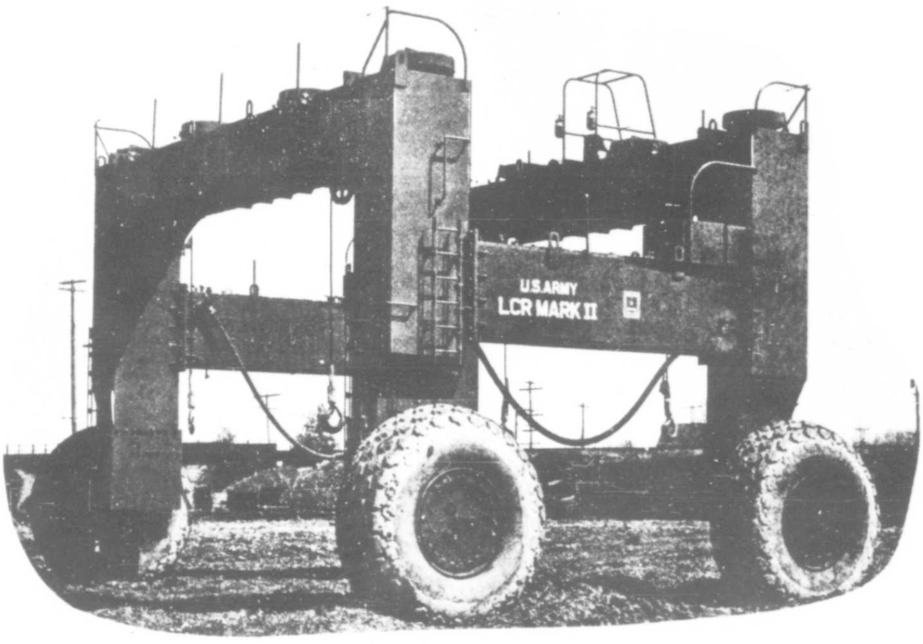
FOR DISCUSSION REFER TO PAGE 8-6



A. ROSS STRADDLE CARRIER



B. TRAVELIFT



C. LANDING CRAFT RETRIEVER

FIGURE 8-15
MOBILE COMPONENT HANDLING EQUIPMENT

FOR DISCUSSION REFER TO PAGE 8-7

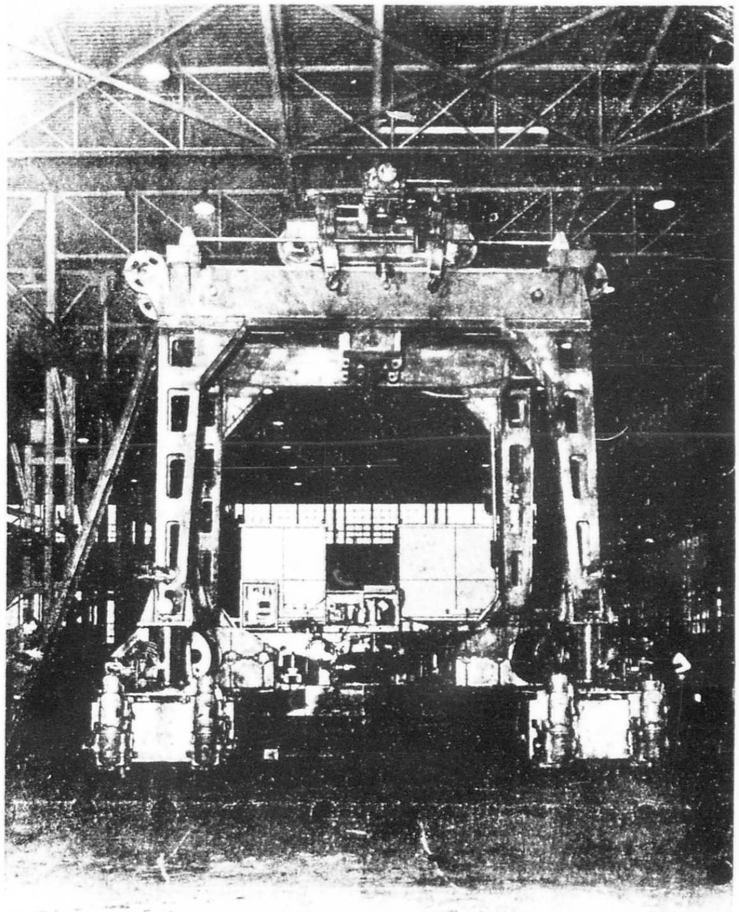


FIGURE 8-16
110 TON MOBILE REFUELING CRANE

(SUPPLIED BY MANNING, MAXWELL AND MOORE CO.)

DESIGN CHARACTERISTICS

Main Hoist	110-Ton Capacity
Auxiliary Hoist	2 and 15-Ton Capacities
Travel Speed	30 FPM
Control Station	One Stationary, One Pendant
Main Hoist Speeds	0 FPM to 15 FPM
Travel Motions	Straight forward and reverse Skew left and right (forward and reverse) Turn left and right (forward and reverse) Rotate clockwise and counter-clockwise

FOR DISCUSSION REFER TO PAGE 8-7

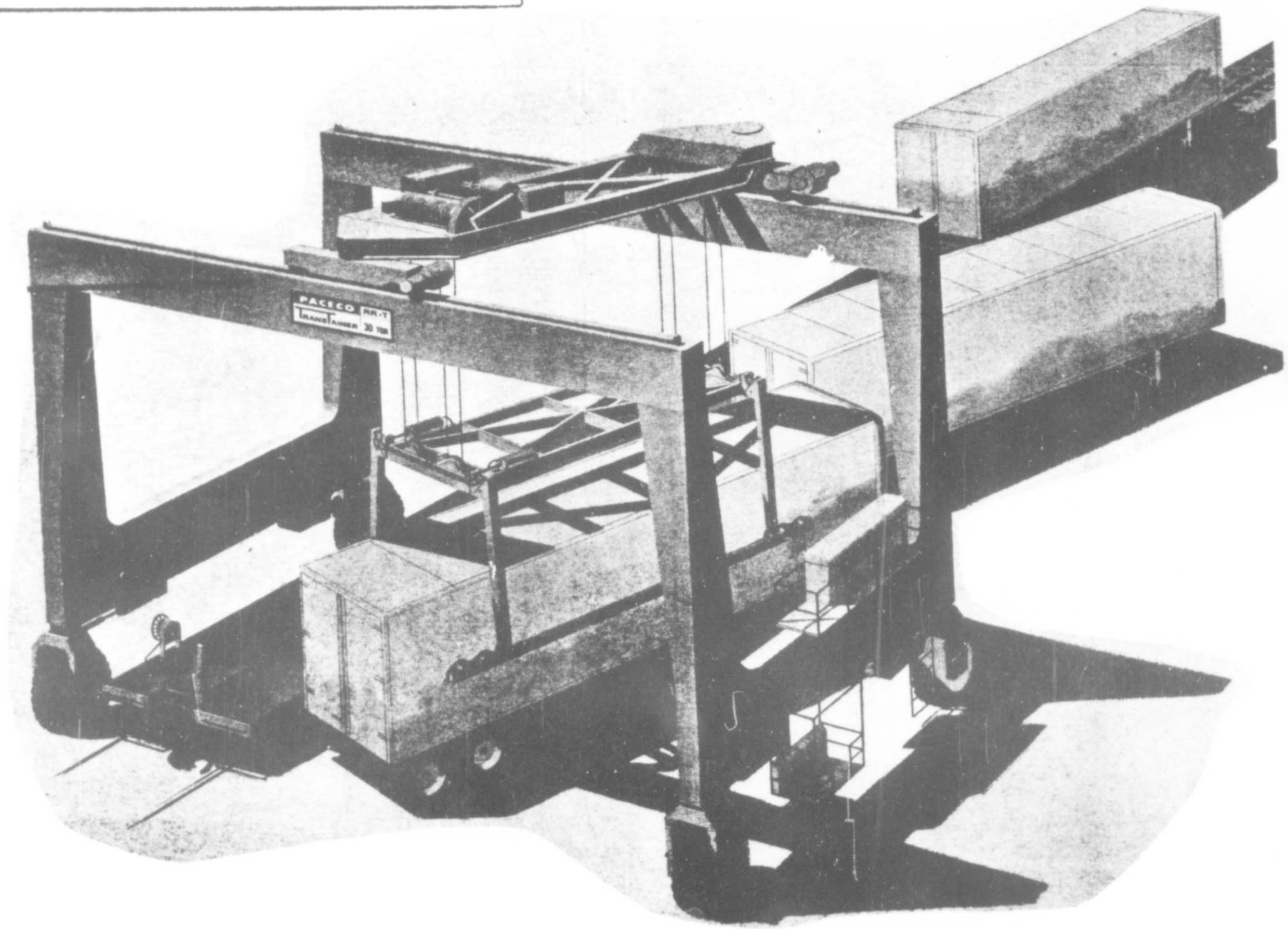


FIGURE 8-17
MOBILE COMPONENT HANDLING DEVICE
(TRANSTAINER)
(SUPPLIED BY PACIFIC COAST ENGINEERING CO.)

FOR DISCUSSION REFER TO PAGE 8-8

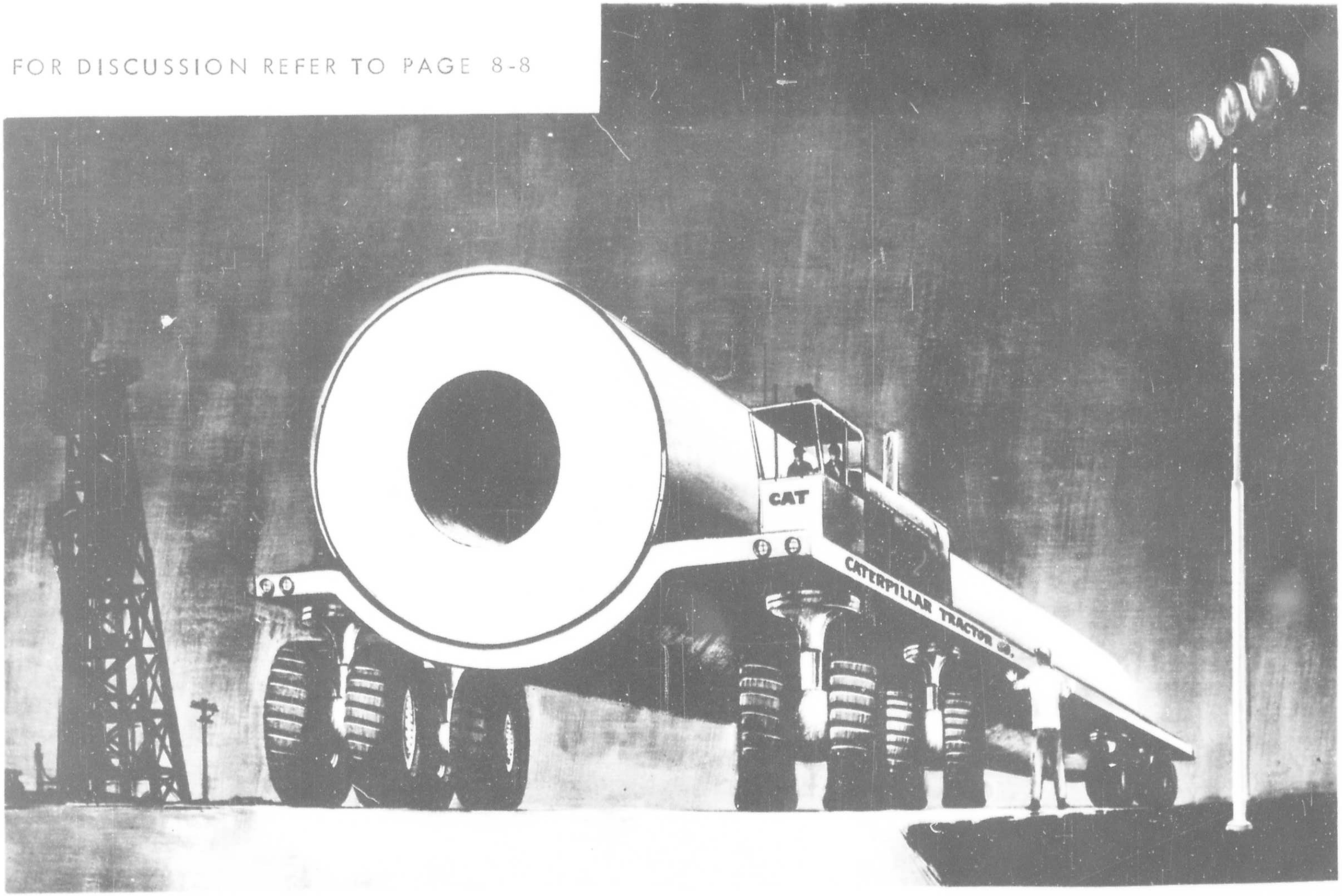
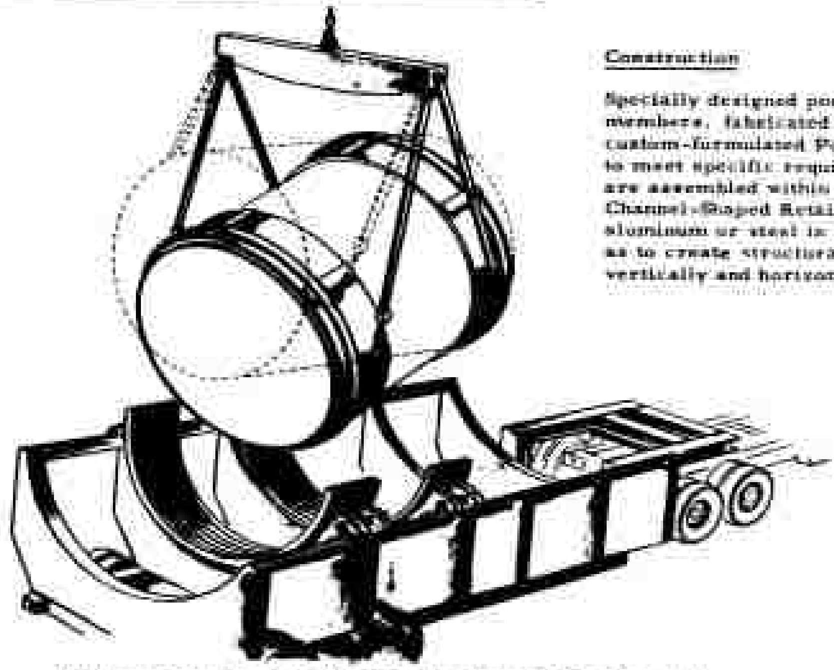


FIGURE 8-18
SEGMENT HANDLING DOLLY
(SUPPLIED BY CATERPILLAR TRACTOR COMPANY)

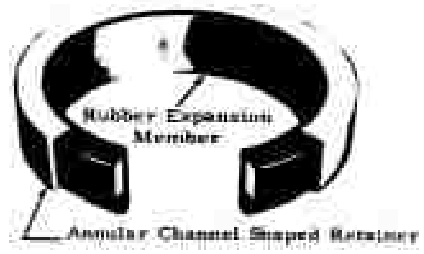
FOR DISCUSSION REFER TO PAGE 8-8



Stiffleg Rotation System Utilizing the Pneuma-Grip Principle

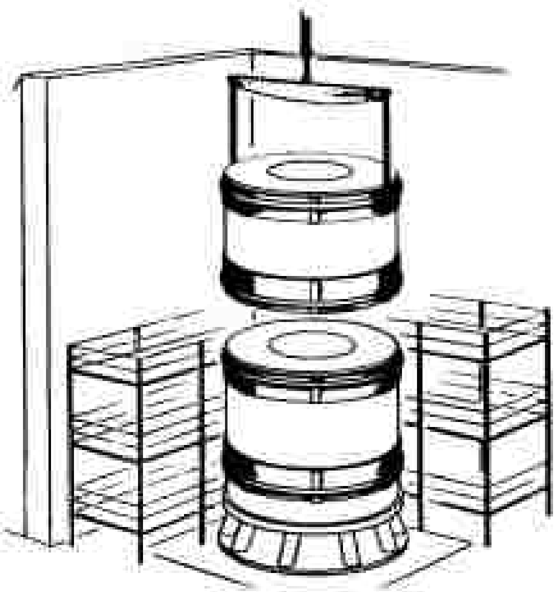
<u>Construction</u>

Specially designed pneumatic members, fabricated from custom-formulated Polymers to meet specific requirements, are assembled within an Annular Channel-Shaped Retainer of aluminum or steel in such a way as to create structural strength, vertically and horizontally.



<u>Operation</u>

Upon the introduction of controlled air (or fluid) into the pneumatic member, the unsupported face expands, thus contacting the load evenly and with a completely balanced peripheral pressure. Gripped in this fashion, the load can then be gently lifted, held in place, turned, or transported without damage.



Positioning of Large Solid Motor Segments

FIGURE 8-19
PRINCIPLES AND APPLICATIONS OF PNEUMA-GRIP
(SUPPLIED BY PRESPRAY CORP.)

FOR DISCUSSION REFER TO PAGE 8-8

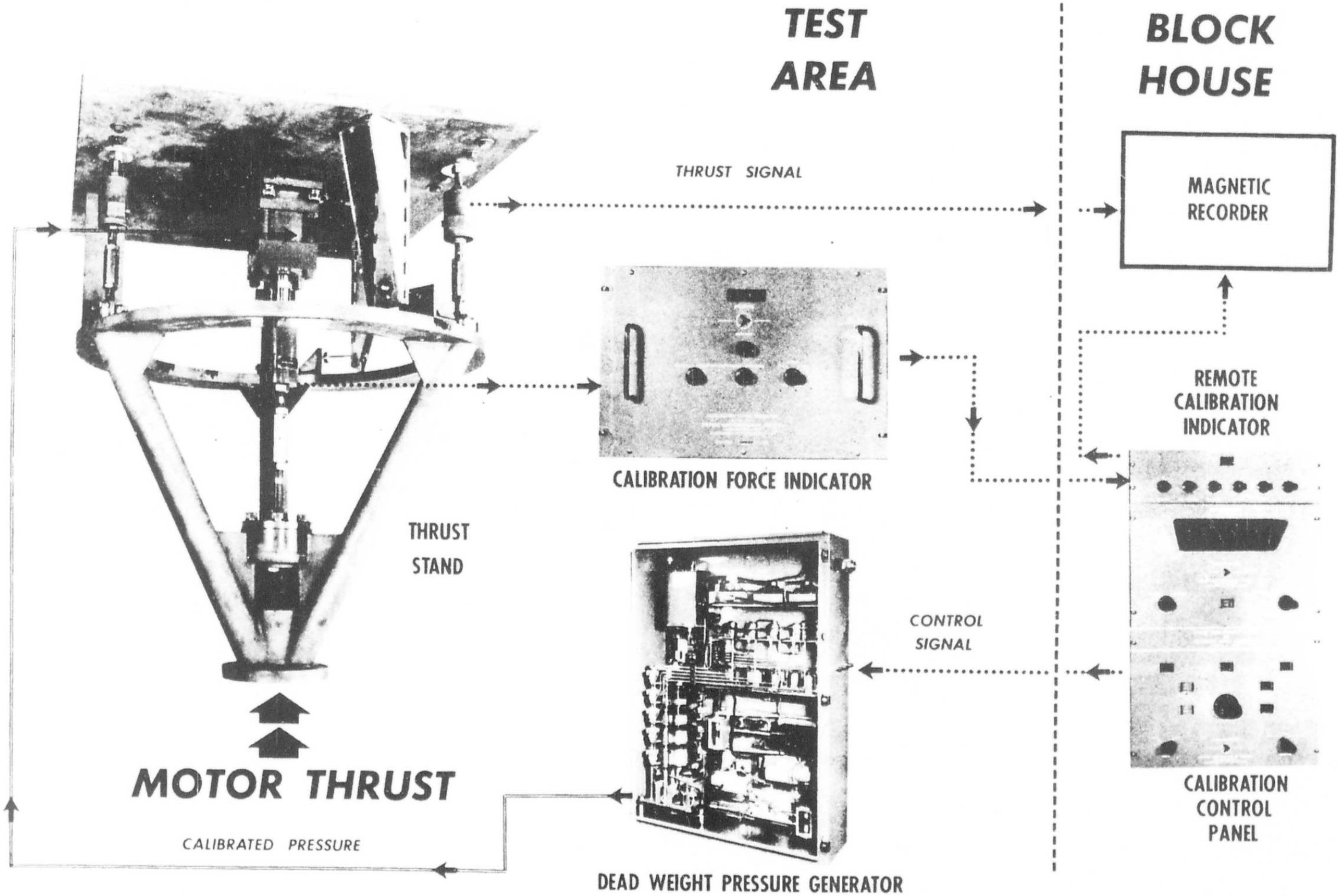
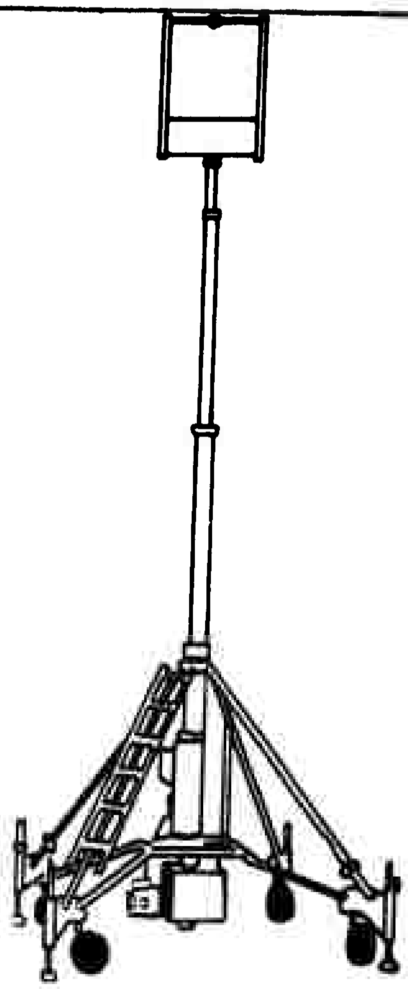


FIGURE 8-20

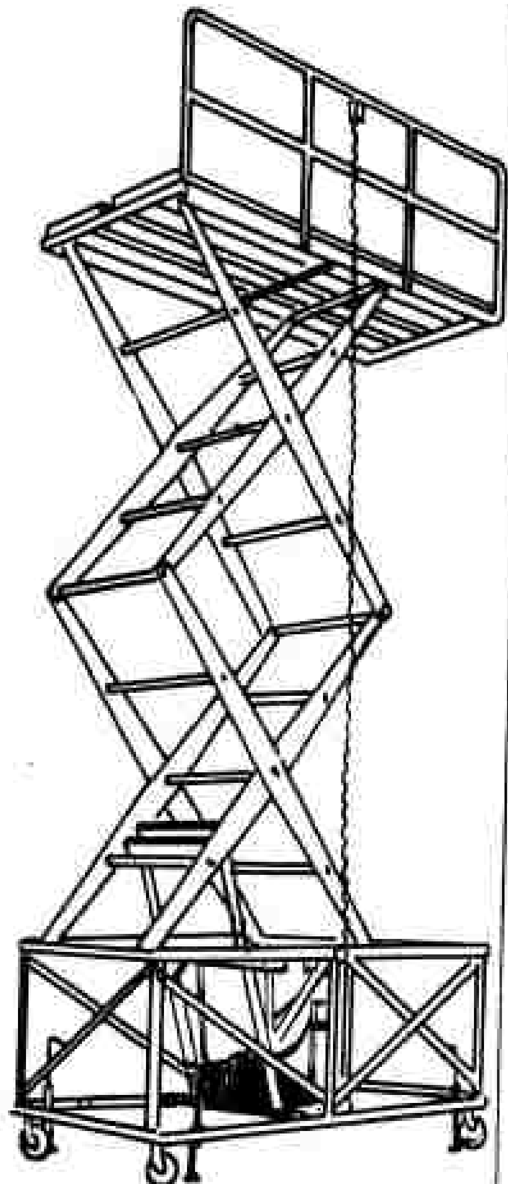
THRUST STAND with REMOTE CONTROL HYDRAULIC CALIBRATOR

(SUPPLIED BY THE NEPTUNE METER CO.)

FOR DISCUSSION REFER TO PAGE 8-8



HYDRAULIC MOBILE ACCESS LIFT



HYDRAULIC WORK PLATFORM

FIGURE 8-21
MOBILE WORK PLATFORMS
(SUPPLIED BY THE BALLYMORE COMPANY)

SECTION 9
TRANSPORT MODES AND EQUIPMENT

1. GENERAL

This section describes water, rail, highway and air transportation as applicable to the solid rocket motors and components covered in this study. For each mode, typical equipment is highlighted.

The following brief conclusions have been drawn:

1) Water Transport - Can handle all presently envisioned sizes and weights. The principal problems associated with water transportation are: The time factor involved and the need for loading equipment where transfer from land to water is necessary.

2) Rail Transport - The largest motor component which can be handled by rail is the 156-inch segment. Specially cleared routes are needed from the manufacturer's plant to the ultimate destination.

3) Long Distance Highway Transport - Can accommodate diameters up to 13 feet and weights up to 100,000 lbs. Short distance highway transport capacities, however, are dependent on the route taken. Special equipment and modification of roads will generally overcome size limitations.

4) Air Transport - Can accommodate the 120-inch segment. However, because of the high cost, this should only be considered as an emergency measure.

2. WATER

a. General.

Water transportation offers a wide selection of equipment capable of handling the sizes and weights contemplated for most solid motors. This method lends itself particularly well to the movement of large quantities of material at relatively low cost, where time is not a governing factor. The type of carrier selected is dependent upon the water route taken (inland or ocean) and upon the quantity of cargo which is to be transported. In general, equipment is available to meet the requirements of the solid motors envisioned within this study, except for the fact that for the larger monolithic motors, structural modifications are necessary to permit better load distribution. One major problem with water transportation is the fact that shore-based facilities of the capacities required are not normally available.

As part of the industry survey, a number of companies involved in marine transport were contacted for information on costs, speeds of tow, barge sizes and tug sizes for various shipments of solid motors (both segment and unitized motors). The following companies have been most helpful in supplying information on this subject.

Gulf Atlantic Towing Corp.
S. C. Loveland Company, Inc.
Seaboard Shipping Corp.
Todd Shipyards Corp.

Tables 9-1 through 9-3, pages 9- 6 through 9- 8 indicate barge sites, costs and speeds of tow for various barge and tub combinations used in inland, coastal and oceangoing transport. This table includes information supplied by all of the above companies. Since the data supplied were overlapping, individual items in the table cannot be credited to any one company. Figure 9-1, page 9-11 shows typical barges that could be used for transporting solid motors.

In general, current charter costs can be estimated roughly at about $1.00 per horsepower per day for tugs and about 10 cents per net ton per day for an ordinary deck barge. The need for heavier than usual decking and internal bracing to support the concentrated weight of loading ramps, as well as the need for ballast pumps, will raise these costs.

It has also been suggested that all barges for offshore use have improved bows to increase speed. The number of segments or motors that can be carried at any one time is dependent on the water depths along the route to be taken. For a launch site at Cape Canaveral, the loaded draft of the vessel must be held to about 7 feet when using the Banana River. Proposals to dredge the Banana River to a depth of 12 feet are presently being studied. Other controlling dimensions along the inland waterway involve horizontal and vertical clearances imposed by various bridges and cables. Table 9-4, page 9-9 is a table of the controlling dimensions along the Atlantic Coast section of the Inland Waterway from Jekyll Island, Ga. to Key West, Fla. The information contained in this table was obtained from a U.S. Army Corps of Engineers document entitled "The Intracoastal Waterway-Atlantic Section". The controlling dimensions along this waterway as taken from this table are:

North of Cape Canaveral
Horizontal Clearance - 55 ft. at the Haulover Canal (Allenhurst)
Vertical Clearance - 80 ft. various overhead cables

South of Cape Canaveral
Horizontal Clearance - 55 ft. Jupiter Island, Swing Bridge
Vertical Clearance - 55 ft. Miami (36th St. Causeway)

It is the consensus of a majority of the marine transporters contacted that units weighing 500 tons could be transported with existing equipment; 1000-ton units would, in some cases, require slight modifications to existing equipment. For 2500-ton units, barges would have to be built for inland use, but modified existing equipment could be used for coastwise or ocean-going transport. For 5000-ton units, it would be necessary to use either existing coastal or ocean-going barges, either modifications of existing ones or new ones. In all cases, the methods of handling the units and the requirement for environmental conditioning could dictate whether existing equipment could be used as is or modified, or whether new equipment would have to be built. One of the principal factors in determining the cost of transportation is utilization of the equipment. If a special barge were built and used for only eight or ten trips per year, the cost would be considerably greater than if standard equipment could be assigned as required or if the equipment could be utilized continuously.

Figure 9-2, page 9-12 depicts all the major inland waterways in the United States and their depths. The map also indicates proposed future extensions of these waterways.

Figure 9-3, page 9-13 superimposes the inland waterways on a complete map of the United States and also indicates 13 ft. 8 in. railroad clearance routes as projected by the Defense Traffic Management Service (DTMS) from the four major solid propellant motor manufacturers to Cape Canaveral. Details of the rail routes shown may be found in Tables 9-5 and 9-6, pages 9-20 and 9-21. From this superimposition it became apparent that a feasible route might use rail or truck transportation to a connecting inland waterway somewhere in the midwest, with subsequent barging to the Gulf Coast and thence to Cape Canaveral. This idea led to the previously discussed transportation study performed by the DTMS.

In addition to barge and tug costs, some cost data has been obtained on ship chartering. According to the Marine Chartering Company, it would cost $1700 per day (including fuel) to rent a 4000 ton ship capable of carrying 2000 tons of cargo. The cost for a 10,000 ton ship with a cargo capacity of 4000 tons would be $2000 per day (including fuel). Both vessels would be capable of moving at a speed of 10 knots. If passage through the Panama Canal were required it would cost $3000 and $5500 respectively for the two vessels for each passage through the canal.

b. Typical Equipment.

Figure 9-4, page 9-14 presents a concept drawing of a 300-ton amphibious lighter supplied by the Army Transportation Command, Ft. Eustis, Va. The applicability of this particular vehicle was discussed during a visit by AMF and Edwards personnel to Ft. Eustis. One advantage of this type of vehicle would be the fact that no harbor facilities would be required. The vehicle could easily emerge from any navigable waterway and also travel long distances over land. There appears to be no problem in building a 500-ton lighter of this design. The following specifications apply to this unit: gross weight - 500 tons, maximum horsepower - 2020 HP, continuous horsepower - 1300 HP, normal range - 240 miles, speed in water - 12 miles per hour, speed on land - 10 miles per hour, crew - 6 men. The turning radius is approximately 116 ft. when all wheels are turning. The draft, when fully loaded, is 9 ft.

FOR DISCUSSION REFER TO PAGE 9-3

TABLE 9-1

COMMERCIAL BARGES FOR INLAND WATERWAY USE

TYPE	OVERALL LENGTH (FT)	OVERALL BREADTH (FT)	DRAFT		CAPACITY SHORT TONS	TUG SIZE (HP)	TOW SPEED KNOTS	BARGE RENTAL	TUG RENTAL
			LOADED	LIGHT					(Per Day)
FLAT DECK	120	35	6.0	2.0	500	400 500	5-6 6-7	$ 55	$ 400 $ 500
FLAT DECK	110	30	6.5	2.0	600	400	5-6	$ 75	$ 400
HOPPER	175	26	9.0	3.0	900	500	6-7	$ 100	$ 600
HOPPER	175	26	9.5	3.0	1000	650	6-7	$ 120	$ 650
HOPPER	165	36	9.0	3.0	1400	700	6-7	$ 175	$ 700
HOPPER	200	45	11.0	3.0	1500	2 @ 400	5-6	$ 150	2 @ $ 400
HOPPER	195	35	12.5	4.5	1750	500	6-8	$ 175	$ 750
HOPPER	195	35	13.5	4.5	2100	500	6-8	$ 225	$ 750
HOPPER	220	35	10.5	4.0	2200	500	6-8	$ 235	$ 750
HOPPER	300	50	12.0	4.0	3000	2 @ 500	3-5	$ 300	2 @ $ 500
HOPPER	240	55	11.0	4.0	3000	500	6-8	$ 300	$ 750
HOPPER	280	55	12.0	4.5	3500	500	3-7	$ 400	$ 750
HOPPER	274	47	26.5	9.0	4000	500	3-6	$ 400	$ 750

FOR DISCUSSION REFER TO PAGE 9-3

TABLE 9-2

COMMERCIAL BARGES FOR COASTAL WATERWAY USE

TYPE	OVERALL LENGTH (FT)	OVERALL BREADTH (FT)	DRAFT		CAPACITY SHORT TONS	TUG SIZE (HP)	TOW SPEED KNOTS	BARGE RENTAL	TUG RENTAL
			LOADED	LIGHT					(Per Day)
FLAT DECK	110	30	6.5	2.0	600	750	7-8	$ 125	$ 750
FLAT DECK	175	26	9.5	3.0	1000	1200	7-8	$ 225	$ 1200
HOPPER	195	35	8.0	4.5	1000	650	5-6	$ 110	$ 650
HOPPER	200	45	9.0	4.5	1200	650	5-6	$ 135	$ 650
HOPPER	240	40	11.0	3.0	2500	1000	7-9	$ 350	$ 1100
HOPPER	300	50	12.0	4.0	3000	1000	8-9	$ 300	$ 1000
HOPPER	280	55	12.0	4.5	3500	1000	7-9	$ 400	$ 1100
HOPPER	240	55	15.0	4.0	4000	1000	7-9	$ 450	$ 1100
HOPPER	240	55	17.0	4.0	4500	1000	7-9	$ 500	$ 1100

FOR DISCUSSION REFER TO PAGE 9-3

TABLE 9-3

COMMERCIAL BARGES FOR OCEAN-GOING USE

TYPE	OVERALL LENGTH (FT)	OVERALL BREADTH (FT)	DRAFT		CAPACITY SHORT TONS	TUG SIZE (HP)	TOW SPEED KNOTS	BARGE RENTAL	TUG RENTAL
			LOADED	LIGHT					(Per Day)
FLAT DECK	110	30	6.5	2.0	600	750	8–10	$ 200	$ 750
FLATDECK	175	26	9.5	3.0	1000	1500	8–10	$ 300	$ 1200
HOPPER	195	35	8.5	4.5	1000	1000	8–10	$ 110	$ 1000
HOPPER	250	50	9.0	4.0	1500	1200	9–10	$ 200	$ 1200
HOPPER	300	50	11.0	4.5	2500	1200	9–10	$ 300	$ 1300
HOPPER	240	40	9.0	3.0	2500	1500	8–10	$ 400	$ 1500
HOPPER	280	55	12.0	4.5	3500	1500	7–9	$ 450	$ 1500
HOPPER	240	55	15.0	4.0	4500	1500	8–10	$ 550	$ 1500
HOPPER	195	72	13.5	4.5	5000	2500	8–9	$ 600	$ 1500
HOPPER	240	65	26.0	4.0	5000	1500	8–10	$ 600	$ 1500
HOPPER	195	72	20.0	4.5	7500	2500	8–9	$ 750	$ 1500

NOTE: OCEAN-GOING BARGES ARE EQUIPPED WITH MODEL STEEL BOWS

FOR DISCUSSION REFER TO PAGE 9-3

TABLE 9-4

BRIDGES, AERIAL CABLES AND FERRIES CROSSING THE INTRACOASTAL WATERWAY - ATLANTIC SECTION FROM JEKYLL ISLAND, GA. TO KEY WEST, FLORIDA

Location	Type	Clearance (ft.mhw)	
		Horizontal	Vertical
Jekyll Id., Ga. Highway Bridge	Vertical lift	100.0	16.8
S.A.L Ry. of Fernandina, Fla.	" "	90.0	5.2
Fernandina, Highway Bridge	Bascule	90.0	21.6
Sawpit Creek	Aerial cable		80.0
Sisters Creek, Highway Bridge	Bascule	90.0	24.6
4.6 mi. south of St. Johns River	Aerial cable		80.0
" " " " " " "	Bascule	59.5	6.8
7.5 mi. south of St. Johns River	Aerial cable		81.3
" " " " " " "	Bascule	90.0	37.0
Palm Valley	"	80.0	10.0
Vilano Beach	Aerial cable		100.0
" "	Lift	89.7	5.5
St. Augustine	Bascule	76.0	25.0
Crescent Beach	"	80.0	9.3
Flagler Beach	Aerial cable		82.2
" "	Bascule	91.0	14.0
4 mi. south of Flagler Beach	Aerial cable		97.0
" " " " " "	Bascule	91.0	15.5
Ormond	"	89.0	21.3
Daytona Beach (Seabreeze)	"	90.0	20.8
Daytona Beach (Main Street)	"	90.0	22.3
Daytona Beach (Broadway)	Aerial cable		98.3
" " "	Bascule	90.0	20.0
Daytona Beach (Memorial)	"	89.7	21.7
Port Orange	"	92.0	20.9
Coronado Beach	"	91.0	14.0
New Smyrna Beach	Aerial cable		80.0
" " "	Swing	58.0	5.0
Haulover Canal (Allenhurst)	"	55.0	7.4
" " "	Aerial cable		81.9
Titusville	Swing	81.0	9.0
Cocoa	"	80.0	5.2
"	Aerial cable		88.2
Eau Gallie	" "		101.3
" "	Swing	80.5	9.6
Melbourne	"	80.0	6.0
Wabasso	"	60.0	9.3
Vero Beach	Bascule	90.0	22.0
" "	Aerial cable		80.0

FOR DISCUSSION REFER TO PAGE 9-3

TABLE 9-4 (CON'T)

BRIDGES, AERIAL CABLES AND FERRIES CROSSING THE INTRACOASTAL WATERWAY - ATLANTIC SECTION FROM JEKYLL ISLAND, GA. TO KEY WEST, FLORIDA

Location	Type	Clearance (ft.mhw) Horizontal	Vertical
Fort Pierce (North)	Swing	80.0	9.0
Fort Pierce (South)	"	80.0	6.2
" " "	Aerial cable		82.6
Jensen	Swing	60.0	9.0
Sewall Point	Bascule	90.0	28.8
Hobe Sound (north end)	"	80.0	10.5
Jupiter (Jupiter Island)	Swing	55.0	8.7
Jupiter (Jupiter River)	Bascule	91.0	26.2
2.3 mi. south of Jupiter	Aerial cable		85.8
Juno Beach	Bascule	90.0	14.9
2.5 mi. north of Lake Park	Aerial cable		80.0
" " " " " "	Bascule	94.0	25.0
Riviera	"	80.0	16.5
West Palm Beach (Flagler Memorial)	"	80.0	17.5
West Palm Beach (Royal Palm)	"	91.0	14.6
West Palm Beach Southern Blvd.)	"	81.2	14.0
Lake Worth	Bascule	80.0	15.5
Lantana	"	90.2	13.3
Boynton Beach	"	80.0	10.0
Delray Beach (8th Street)	"	80.0	9.7
Delray Beach (Atlantic Ave.)	"	90.0	12.5
Boca Raton (North)	"	80.0	9.2
Boca Raton (South)	"	85.0	9.8
Deerfield Beach	"	91.5	21.7
Pompano Beach	"	89.8	15.1
Oakland Park	"	88.5	22.9
Ft.Lauderdale (10th St.)	"	85.1	16.5
Ft.Lauderdale (Las Olas Blvd.)	"	91.4	31.4
Ft.Lauderdale (SE.17th St.)	"	99.4	25.3
Dania Beach	"	91.0	22.6
Hollywood Beach	Aerial cable		80.0
" "	Bascule	57.6	10.0
Hallandale Beach	Swing	57.0	9.8
North Miami Beach (Fla.)	Bascule	94.3	19.6
" " " "	Aerial cable		87.0
Bay Habor (Broad Causeway)	Bascule	80.0	16.0
Miami (79th St. Causeway)	"	60.0	18.5
Miami (36th St. Causeway)	Fixed	90.0	55.0
Miami (Venetian Causeway)	Bascule	60.0	8.5
Miami (Mac Arthur Causeway)	"	57.0	7.5
Miami (Rickenback Causeway)	"	80.6	23.7
Jewfish Creek	Aerial cable		91.3
" "	Bascule	80.0	11.8
5 mi. north of Bahia Honda	Swing	107.0	24.0
Bahia Honda	Fixed	232.0	20.0

FOR DISCUSSION REFER TO PAGE 9-3

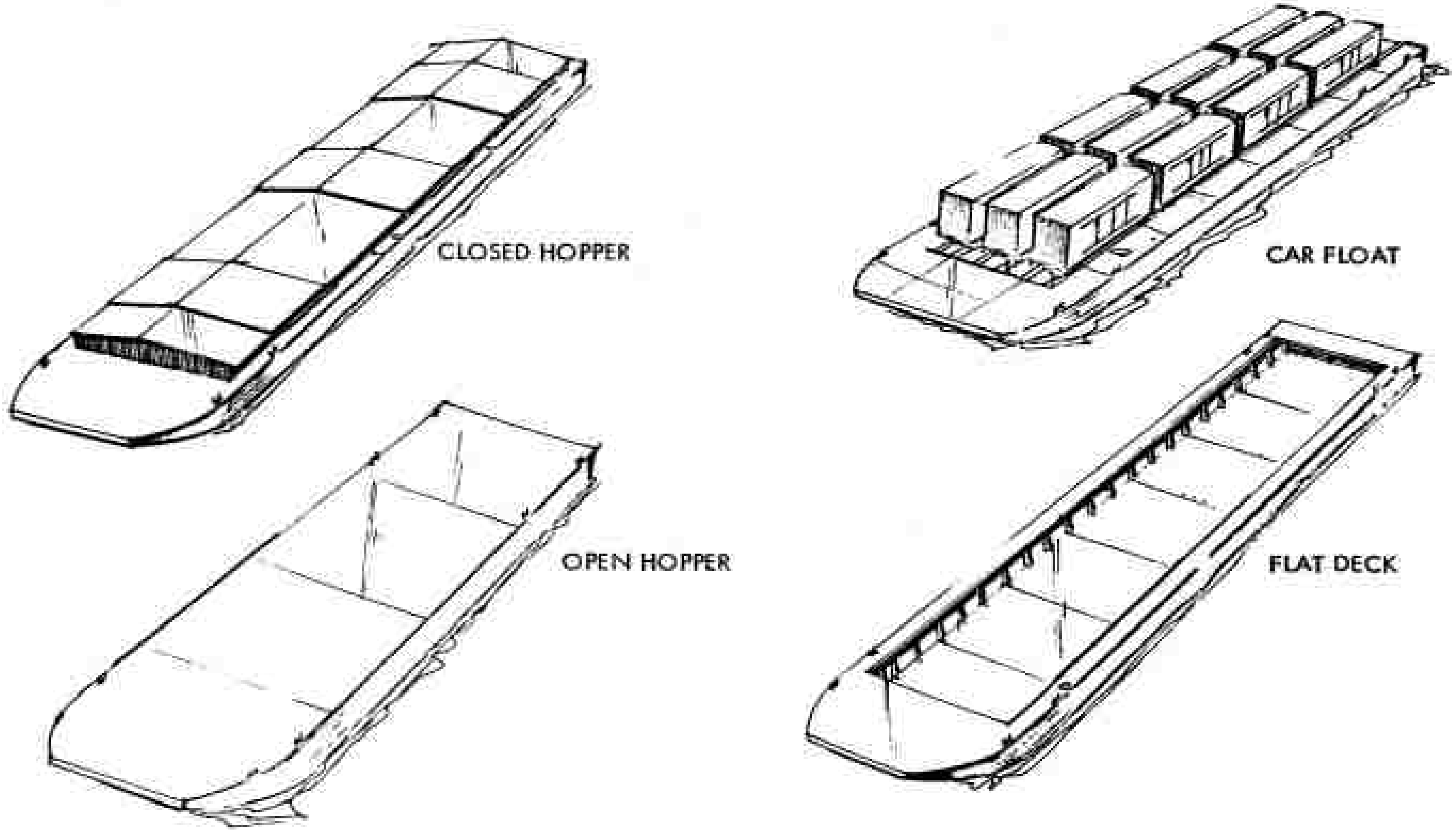


FIGURE 9-1

BARGE TYPES

FOR DISCUSSION REFER TO PAGE 9-4

FIGURE 9-2

FOR DISCUSSION REFER TO PAGE 9-5

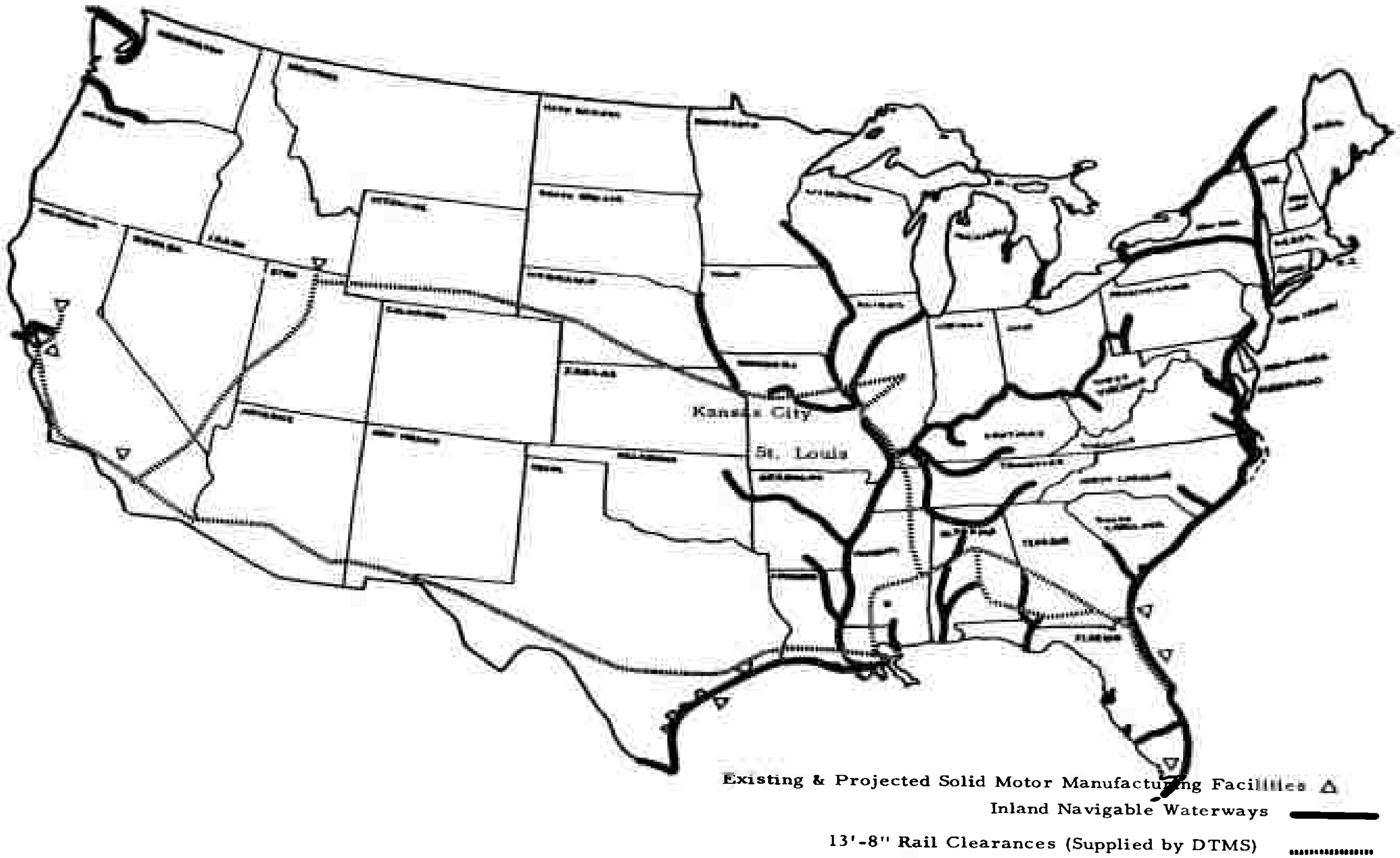


FIGURE 9-3
SUPER-POSITION OF NAVIGABLE WATERWAYS AND 13'8" RAIL CLEARANCES

FOR DISCUSSION REFER TO PAGE 9-5

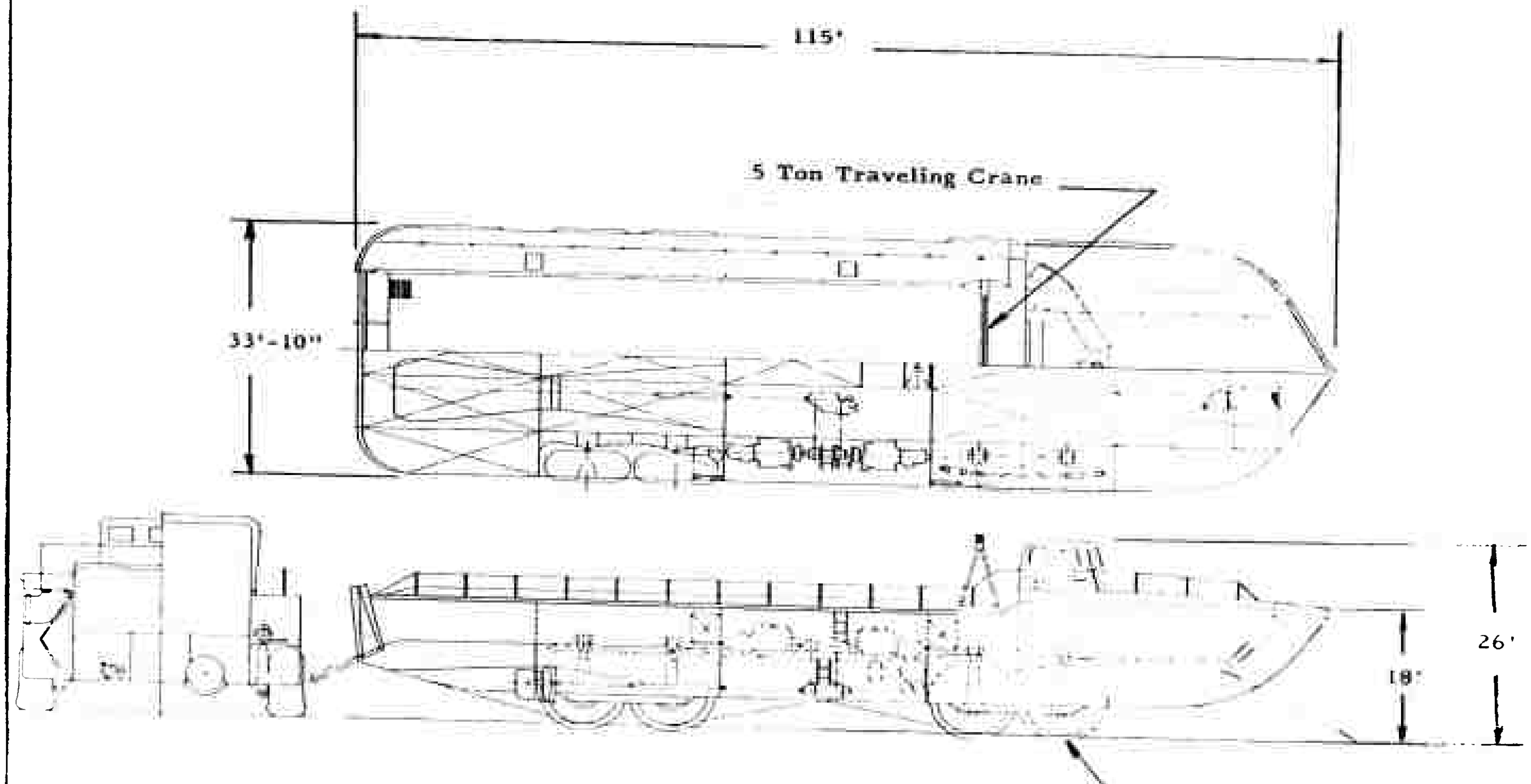


FIGURE 9-4
300 TON AMPHIBIOUS LIGHTER
(SUPPLIED BY THE U.S. ARMY TRANSPORTATION COMMAND)

3. RAIL

a. General.

The following material was essentially supplied by The Defense Traffic Management Service (Western Region) as part of the two rail transportation studies performed for the 6593 d Test Group (Development), Edwards AFB, Calif.

The objective of the first study was to determine the most economical routing of the following packaged Explosive Class B segment.

Diameter - 164 inches
Length - 25 feet
Weight - 340,000 pounds.

Origin points would be one of the following:

1) Aerojet General Corp., Sacramento, Calif.
2) Lockheed Propulsion Co., Redlands, Calif.
3) Thiokol Chemical Corp., Brigham City, Utah
4) United Technology Center, Coyote, Calif.

Destination points would be one of the following:

1) Cape Canaveral, Florida
(railheads - Titusville, Cocoa Rockledge, Fort Pierce)

2) Vandenberg AFB, California
(railhead - Tangair)

3) Edwards AFB, California

Quantities of shipments would range from five (5) to ten (10) segments at one time.

The required clearances for the carriers involved from the four origins mentioned were obtained through the excellent cooperation of the Southern Pacific Railroad.

Routes, estimated transit times and special train service were determined. They can be found in Tables 9-5 and 9-6, pages 9-20, and 9-21.

As established by the railroads, special train service is a necessity to provide for the slowing down of trains to walking speeds through tunnels with close clearances and to maintain rail line traffic control. In confirming the 13 ft. 8 in. diameter clearance, the Southern Pacific RR advised that such clearances were being extended only to DOD/NASA and not to commercial concerns. The reason for this is that such clearances require the assembly of special train crews and make scheduling of equipment difficult. The impact on the railroad companies, organizations, facilities and services to accomplish this task goes far beyond that of the service normally provided.

The clearances received are predicated on the use of a heavy duty rail car similar to Delaware and Hudson Flat Car number 16153. This car's physical characteristics are 45 ft. 4 in. outside length, 10 ft. 0 in. width, 4 ft. 1 in. high from top of rail, 24 ft. 6 in. truck centers, axles spaced 5 ft. 6 in. with two (2) four axle trucks and a total gross weight capacity (including car) of 502,000 pounds. Few cars of this type exist. The number of cars required should be determined after a contract is placed at which time the rail line serving the origin point should be approached with the idea that it acquire the required cars as part of its fleet.

The loaded dimensions utilizing a car similar to D and H 16153 are not to exceed:

17 ft. 10 in. above top of rail - no width
11 ft. 0 in. above top of rail - 13 ft. 8 in. wide
8 ft. 2 in. above top of rail - 12 ft. 10 in. wide
6 ft. 2 in. above top of rail - 11 ft. 10 in. wide
4 ft. 2 in. above top of rail - 10 ft. 8 in. wide

Figure 9-5, page 9-23 depicts the proposed clearance envelope.

Since packaging and rail car securements for this size segment would deviate from existing Interstate Commerce Commission (T. C. George's Tariff number 13) and AAR regulations, Air Force and DTMS action will be required to secure special ICC permit and AAR approval. This action should be taken at such time as rail car and prototype shipment is available for testing in accordance with Bureau of Explosives, AAR test standards. Request to conduct the test should be forwarded to DTMS Headquarters in accordance with DTMS Regulations, AR 705-8, Paragraph 213008.

Rail transportation costs applicable to the above shipment cannot be determined until origin point, shipment conditions, volume and generation rate are known, DTMS Headquarters has been alerted to the possible future need for rate negotiation on these segments and official action can be taken whenever the necessary information becomes available.

The objective of the second study was to determine if the mass movement of rocket motor segments from the manufacturing facility to Cape Canaveral might be carried out more economically by a combination of rail and water transport.

A study was performed using the following criteria:

1) The dimension and weights to be used for the optimum shipping package are:
   Diameter: 164 inches
   Length: 25 feet
   Weight: 340,000 lbs.
   Explosive Class: 2B

2) Determination of the most practical and economical railroad routing for the optimum package as follows:

   From: Sacramento, Calif.
   Coyote, Calif.
   Redlands, Calif.
   Brigham City, Utah

   To each of the following:

   Kansas City, Mo.
   St. Louis, Mo.
   Little Rock, Ark.
   Houston, Texas
   New Orleans, La.

3) Determination of cost and shipping time for each rail-route evaluated. It may be assumed that as many as 10 of the optimum packages may be shipped at the same time.

4) Determination of cost and shipping time to transport 10 of the optimum packages, by barge, from Kansas City, Mo., St. Louis, Mo., Little Rock, Ark., Houston, Texas and New Orleans, La., to Cape Canaveral, Fla. Off-loading facilities at each of these cities will be ascertained.

5) Determination of the quantities and type of equipment available to accomplish the requirements for barge transportation.

The results of the study can be found in Table 9-7, page 9-22. In addition to the tabular information, the following material was also obtained:

1) The listed costs via rail all the way were based on present class 55 rates of $6.26 per one hundred pounds. At this time no consideration was given to the possibility of negotiating a lower Section 22 rate. However, it is almost a certainty that such a rate would be negotiated, since the present cost for 10 segments in one shipment would be $212,840 at the existing rate. There is a wide area for rate negotiation at this cost level and a reduction, of even 10%, would provide substantial savings over a long period of time.

2) Water rates were received via direct inquiry with barge operators. It is therefore questionable as to whether lower rates can be negotiated. In addition, transfer facilities would have to be provided since none exist which are capable of handling loads of 340,000 lbs. The initial cost of setting up such a facility plus the operating costs, while not known, would undoubtedly be substantial.

3) In view of the additional handling required at rail barge transfer points, and the uncertainty of construction of the proposed rail facility directly into Cape Canaveral, it is the Western Traffic Regions recommendation that transportation planning for 156-inch diameter segments be based on through rail service.

4) Barge transportation cost data was unobtainable between Kansas City and Cape Canaveral.

b. Typical Equipment.

An apparent problem of rail transportation is the high degree of shock imposed upon loads during "humping" (rail car coupling). A number of shock absorbing devices have been developed by various organizations. A typical unit is shown in Figure 9-6, page 9-24, The "Hydra-Buff"), manufactured by the A. O. Smith Corp. is an end-of-car device which is capable of handling up to 210,000 lbs. total weight. Shock absorbing devices manufactured by

other companies may be supplied as an integral unit with the undercarriage of the rail car. The A. O. Smith "Hydra Buff" will limit the maximum coupling force to less than 400,000 lbs. for a 14 mile per hour impact of a fully loaded, 50 ton car. Since the "Hydra Buff" is mounted on the end of the rail car, the cushioning effect is multiplied when more than one device is placed in series in a train of cars. This characteristic is especially interesting in the transportation of heavy items, since many roadbeds, trestles, bridges, etc. will not support the concentrated load resulting from more than one loaded freight car. As a result, several empties must be placed ahead and behind each fully loaded car. In this situation the use of empty "Hydra Buff"-equipped cars immediately before and behind the load car will provide a cushioning capacity of up to 1 million foot lbs. per car, in contrast to a single unit which will only absorb 500,000 ft. lbs. of energy on impact. The cost of this unit per car is approximately $2400.00.

Other companies which have supplied literature on equipment capable of providing shock attenuation are: Hydra-Cushion Inc., Keystone Railway Equipment Co. and Pullman-Standard.

Another method of shock attenuation of segments riding on railcars is to provide each segment with its own individual shock attenuation pallet. This method is being proposed by the Lord Manufacturing Co. of Erie, Pa. and is called a Dyna-Dec, (See Figure 9-7, page 9-25). The maximum transmitted longitudinal shock for a 100,000 lb. mass under a twelve mile per hour impact would be 3 "g's". The Dyna-Deck mount would also provide transverse and axial shock attenuation.

FOR DISCUSSION REFER TO PAGE 9-15

TABLE 9-5

DEFENSE TRAFFIC MANAGEMENT SERVICE

RAIL TRANSPORTATION STUDY

ORIGIN	DESTINATION	ROUTING	MINIMUM TRANSIT TIME	COMMENTS
THIOKOL CHEMICAL CORPORATION CORRINE, UTAH	Cape Canaveral Titusville Cocoa Rockledge Fort Pierce	UP - Kansas City - GM&O - Birmingham - L&N - Montgomery - ACL - Benson Jct. - FEC.	17 days	Special train service at rate of $7. 30 per mile in addition to regular freight charges will be necessary on ACL -425 miles and GM&O -872 miles.
		UP - Colton - SP - New Orleans - IC - Jackson - GM&O - Birmingham - ACL - Benson Jct. - FEC	17 days	Special train service at rate of $7. 30 per mile in addition to regular freight charges on IC - 280 miles, GM&O - 319 miles, ACL - 425 miles will be necessary.
	Edwards AFB	UP - Barstow - AT&SF	5 days	
	Vandenberg AFB (Tangair)	UP - Colton - SP	7 days	
UNITED TECHNOLOGY CORP COYOTE, CALIFORNIA	Cape Canaveral Titusville Cocoa Rockledge Fort Pierce	SP - New Orleans - IC - Jackson - GM&O - Birmingham - L&N - Montgomery - ACL - Benson Jct. - FEC	21 days	Special train service at rate of $7. 30 per mile, in addition to regular freight charges will be necessary between the following points: From San Jose to Los Angeles, 466. 8 miles, from New Orleans to Jackson, 280 miles, from Jackson to Birmingham, 319 miles, and from Montgomery to Trilby, 425 miles.
	Edwards AFB	SP - Mojave - AT&SF	4 days	Special train service, at rate $7. 30 per mile, in addition to regular freight charges will be necessary from San Jose to Mojave, 365. 6 miles.
	Vandenberg AFB (Tangair)	SP	4 days	Special train service will be necessary, at rate of $7. 30 per mile in addition to regular freight charges, from San Jose to Tangair, 617. 8 miles.

FOR DISCUSSION REFER TO PAGE 9-15

TABLE 9-6
DEFENSE TRAFFIC MANAGEMENT SERVICE

RAIL TRANSPORTATION STUDY

ORIGIN	DESTINATION	ROUTING	MINIMUM TRANSIT TIME	COMMENTS
AEROJET GENERAL CORP. NIMBUS, CALIFORNIA	Cape Canaveral Titusville Cocoa Rockledge Fort Pierce	SP - New Orleans - IC - Jackson - GM&O Birmingham - L&N - Montgomery - ACL - Benson Jct. - FEC	21 days	Special train service at rate $7.30 per mile in addition to regular freight charges will be necessary from Nimbus to Los Angeles, 477.7 miles, from New Orleans to Jackson, 280 miles, from Jackson to Birmingham, 319 miles and from Montgomery to Trilby, 425 miles.
	Edwards AFB	SP - Mojave - AT&SF	4 days	Special train service at rate $7.30 per mile, in addition to regular freight charges will be necessary from Nimbus to Mojave, 376.5 miles.
	Vandenberg AFB (Tangair)	SP	4 days	Special train service at rate $7.30 per mile, in addition to regular freight charges will be necessary, 633.9 miles.
LOCKHEED PROPULSION REDLANDS, CALIFORNIA (MAIN LINE STATION)	Cape Canaveral Titusville Cocoa Rockledge Fort Pierce	SP - New Orleans - IC - Jackson - GM&O Birmingham - L&N - Montgomery - ACL - Benson Jct. - FEC	18 days	Special train service at rate $7.30 per mile in addition to regular freight charges will be necessary from New Orleans to Jackson, 280 miles, from Jackson to Birmingham, 319 miles and from Montgomery to Trilby, 425 miles.
	Edwards AFB	SP - Mojave - AT&SF	4 days	Special train service at additional rate not required
	Vandenberg AFB (Tangair)	SP	4 days	Special train service at additional rate not required

FOR DISCUSSION REFER TO PAGE 9-18

TABLE 9-7

DEFENSE TRAFFIC MANAGEMENT SERVICE

STUDY OF RAIL COSTS VS RAIL-BARGE COSTS

	NIMBUS	SUNNYVALE	REDLANDS	BRIGHAM CITY
Through Rail Special Train Service	340,000# @ $6.26 x 10 - $212,840.00 1502 miles @ $7.30 - $10,964.60 $223,804.60	340,000# @ $6.26 x 10 - $212,840.00 1491 miles @ $7.30 - $10,884.30 $223,724.30	340,000# @ $6.26 x 10 - $212,840.00 1024 miles @ $7.30 - $7,475.20 $220,315.20	340,000# @ $5.23 x 10 - $177,820.00
Rail to New Orleans Special Train Service Barge Beyond	340,000# @ $4.95 x 10 - $168,300.00 478 miles @ $7.30 - $3,489.40 170 tons @ $10.00 x 10 - $ 17,000.00 $188,789.40	340,000# @ $4.95 x 10 - $168,300.00 467 miles @ $7.30 - $ 3,409.10 170 tons @ $10.00 x 10 - $ 17,000.00 $188,709.10	340,000# @ $4.95 x 10 - $168,300.00 170 tons @ $10.00 x 10 - $ 17,000.00 $185,300.00	340,000# @ $4.42 x 10 - $150,280.00 170 tons @ $10.00 x 10 - $ 17,000.00 $167,280.00
Rail to St. Louis Special Train Service Barge Beyond	340,000# @ $4.95 x 10 - $168,300.00 478 miles @ $7.30 - $ 3,489.40 170 tons @ $14.65 x 10 - $ 24,905.00 $196,694.40	340,000# @ $4.95 x 10 - $168,300.00 467 miles @ $7.30 - $ 3,409.10 170 tons @ $14.65 x 10 - $ 24,905.00 $196,614.10	340,000# @ $4.95 x 10 - $168,300.00 170 tons @ $14.65 x 10 - $ 24,905.00 $193,205.00	340,000# @ $3,66 x 10 - $124,440.00 170 tons @ $14.65 x 10 - $ 24,905.00 $149.345.00
Rail to Houston Special Train Service Barge Beyond	340,000# @ $4.44 x 10 - $150,960.00 478 miles @ $7.30 - $ 3,489.40 170 tons @ $12.80 x 10 - $ 21,760.00 $176,209.40	340,000# @ $4.44 x 10 - $150,960.00 467 miles @ $7.30 - $ 3,409.10 170 tons @ $12.80 x 10 - $ 21,760.00 $176,129.10	340,000# @ $4.44 x 10 - $150,969.00 170 tons @ $12.80 x 10 - $ 21,760.00 $172,720.00	340,000# @ $4.04 x 10 - $137,360.00 170 tons @ $12.80 x 10 - $ 21,760.00 $159,120.00

FOR DISCUSSION REFER TO PAGE 9-16

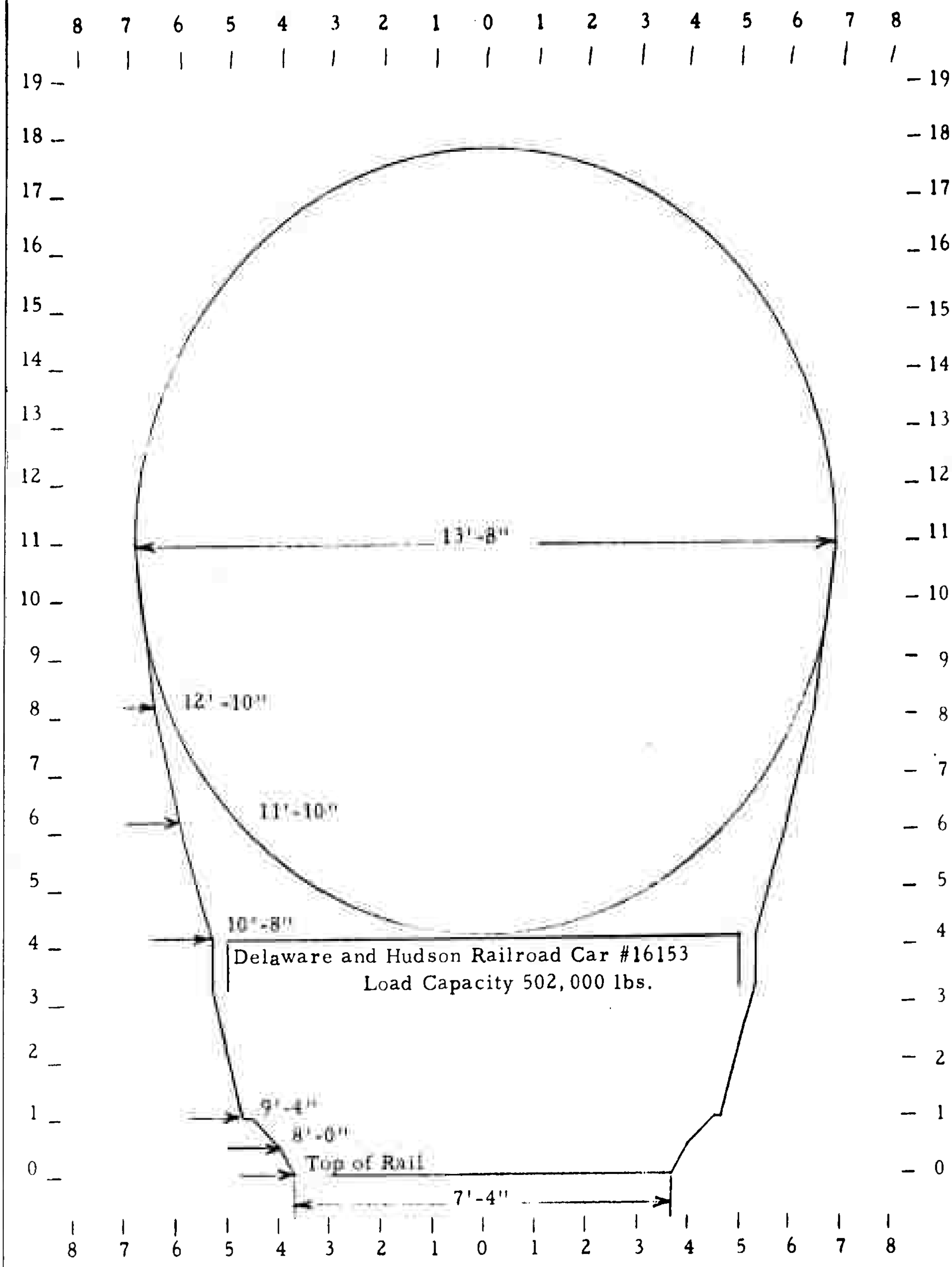
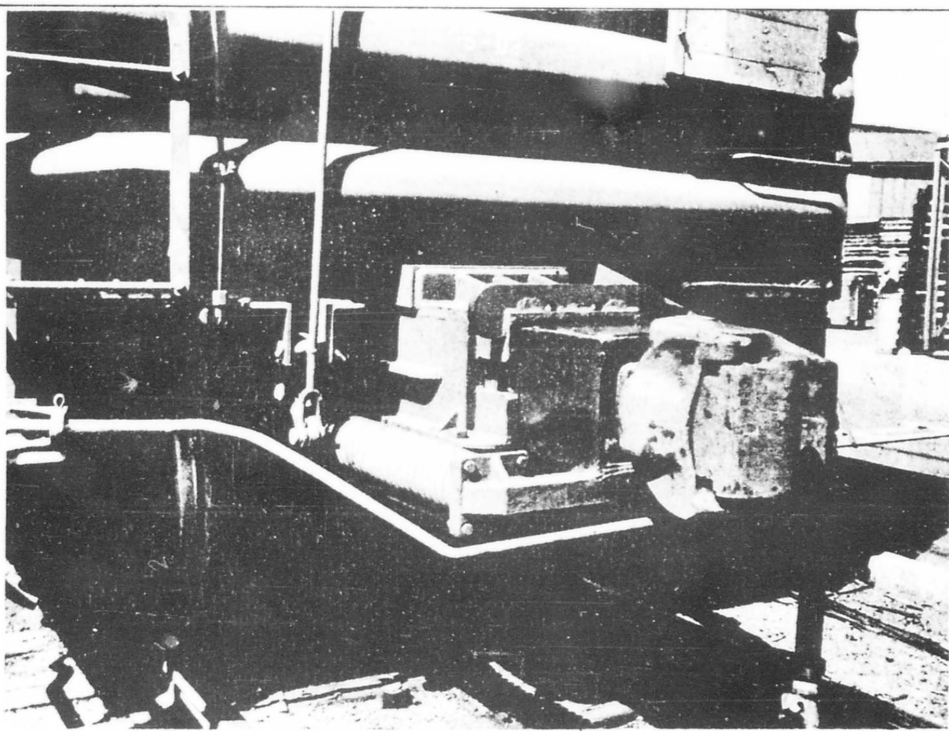


FIGURE 9-5
RAIL TRANSPORTATION STUDY CLEARANCE ENVELOPE
(SUPPLIED BY THE DEFENSE TRAFFIC MANAGEMENT SERVICE)



FOR DISCUSSION REFER TO PAGE 9-18

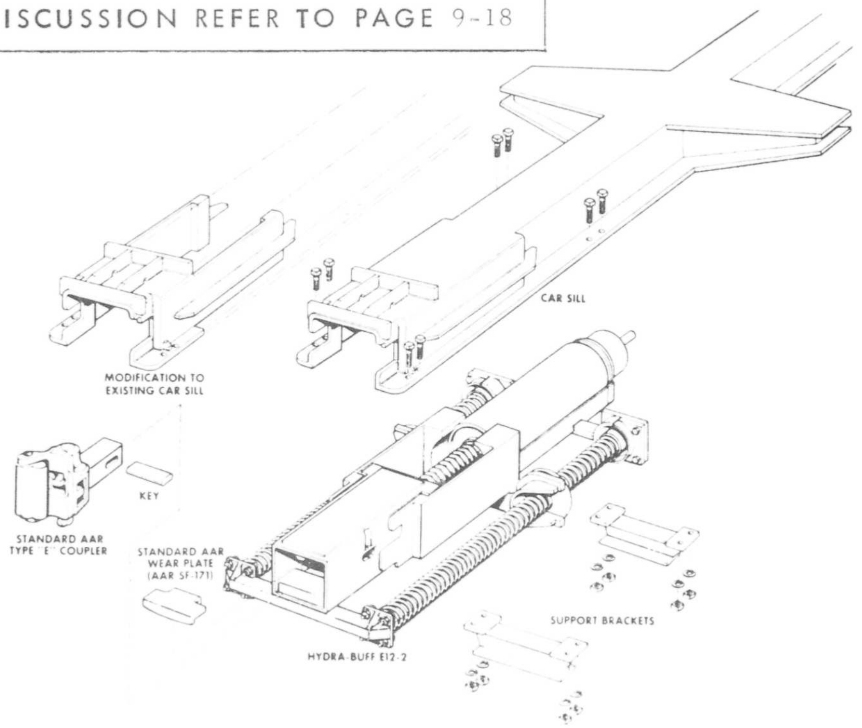


FIGURE 9-6

HYDRA-BUFF SHOCK ATTENUATION DEVICE
(SUPPLIED BY A. O. SMITH CORP.)

FOR DISCUSSION REFER TO PAGE 9-14

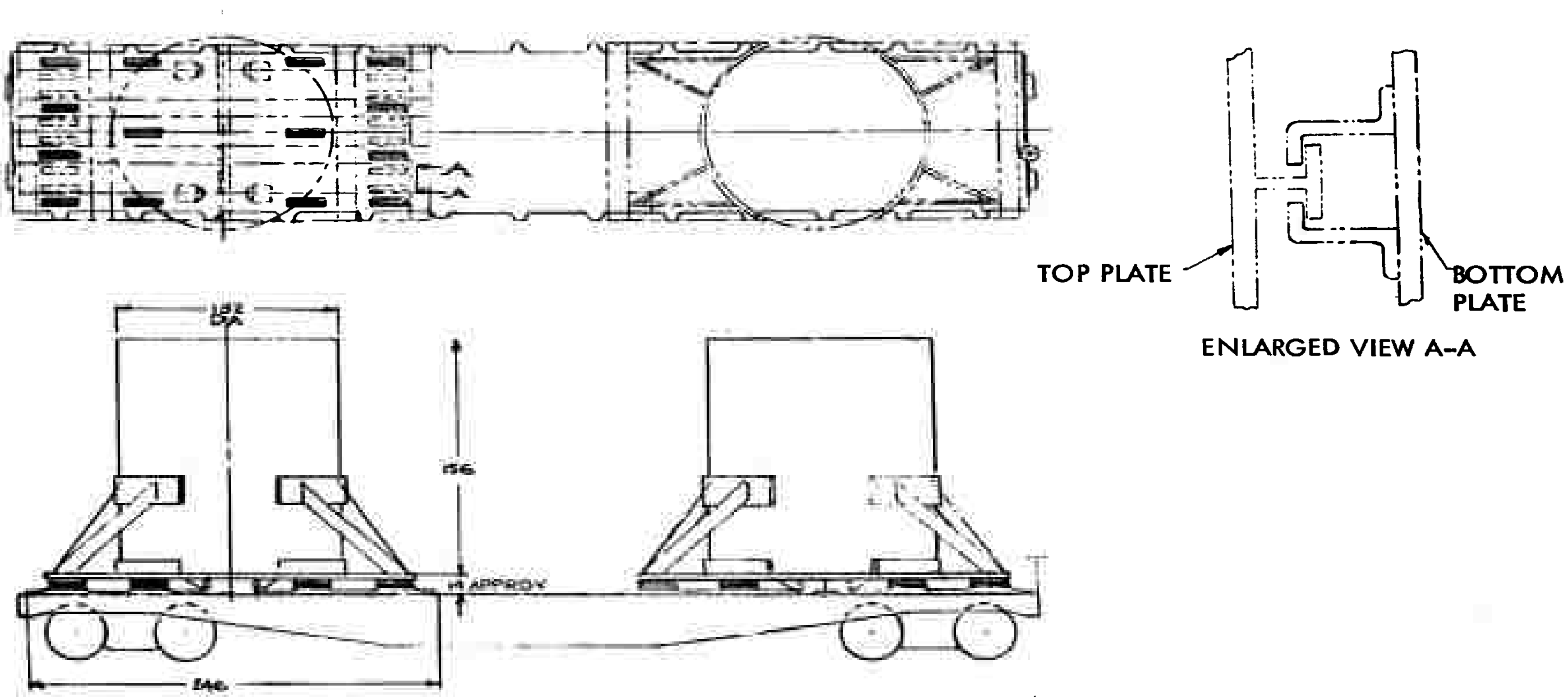


FIGURE 9-7
SEGMENT SHOCK ATTENUATION PALLET
(SUPPLIED BY LORD MANUFACTURING CO.)

4. TRACTOR TRAILER

a. General.

Transport of components of solid propellant rocket motors via highways is feasible in varying degrees. Truck transport generally involves the least number of problems with respect to on-and-off loading. Present restrictions imposed by most states limits the heights of a vehicle to approximately 13.5 ft. The reason for this is that the majority of overpass clearances in the United States are approximately 14 ft. In general, the weight restrictions imposed by the states vary between 60,000 and 100,000 lbs. This limitation is normally only imposed for frequent long haul transportation. For short haul transportation, the maximum axle loading restrictions imposed by the state and the physical characteristics of the route to be traversed normally governs. It is, therefore, possible to transport very heavy loads for short distances, provided the transporter has sufficient axles and wheels so that the axle loading does not exceed approximately 22,000 lbs. (In some states this figure is as low as 18,000 lbs.)

The legal limits for height, width, length and weight for each state can be found in Table 9-8, page 9-30. Permits to exceed these limits have also been granted by many of the states. These limits can also be found in Table 9-8. It has been indicated by some states that, under special conditions, even the permit limits may be exceeded. The limits established by the states do not cover all of the roads within the states. Prior to each shipment, routes must be investigated and the limits adjusted.

Operating restrictions are generally enforced when a shipment is made under permit. These restrictions apply to speeds, operating times (generally limited to daylight hours and weekdays) and to the number of vehicles in the convoy (generally limited to three).

Only a limited amount of cost data has been supplied by concerns involved in truck transportation. This is due to the unwillingness of the commercial carriers to quote rates on undefined sizes, quantities, and frequencies of operation. The cost information that has been obtained is presented below.

Approximate Cost Data for Truck Transportation

Cost Data	Source	Comments
\$8.53 per 100 lbs. on trip from West Coast to Cape Canaveral	USAC Transport Inc.	Overdimensional charge is 35 cents per mile. Additional cost for escort and flagman, \$1200 per man.
Cost between Cocoa Rockledge, Fla. and Cape Canaveral varies between 60 and 70 cents per 100 lbs. depending on load size	Arthur N. Lloyd Inc.	This included cost for off-loading of sements weighing between 65,000 and 125,000 lbs.

b. Typical Equipment.

Figure 9-8, page 9-33 is a 400-ton capacity trailer proposed by Rogers Bros. Corp. for the transport of 220-inch diameter solid motor segments. The trailer is designed with three point suspension to prevent twisting forces from being transmitted to the load. The 16 x 25 tires are each rated at 23,500 lbs. at 5 miles per hour when inflated to 95 psi. Each wheel in the system is equipped with independent pneumatic brakes. A change in bed elevation can be accomplished by means of four (4) hydraulic jacks built into the goosenecks. The bed may be carried at any elevation from zero to 48 inches of roadway clearance. The rear end of the trailer is designed so that it can be readily adapted to power steering, should greater rear end mobility be required. The tractor presently under consideration is equipped with an 800 HP engine. The tractor's rear tires are 18 x 33 and are rated at 25,090 lbs. each at 10 miles per hour and 80 psi inflation, or approximately 35,000 lbs. each at 100 psi and 5 miles per hour. No cost data was supplied relative to this trailer.

Figure 9-9, page 9-34 is a proposed concept for a 350,000 lb. highway transporter by Fruehauf Co. for a 160-inch motor segment supplied by Gulf Atlantic Towing Co. All pertinent information is indicated.

Figure 9-10, page 9-35 represents a concept supplied by Trailmobile Corporation for transporting a 600-ton, 10-foot diameter solid motor. Two similar dollies are located at either end of the bed and are equipped with 64 (11 x 20) 14 ply tire assemblies, 16 - 40,000 lb. capacity axles and 16 - 1/2 x 7 inch airbrakes. All axles are steerable through hydraulic rams. Each dolly is equipped with four (4) gasoline engines with hydraulic pumps and other necessary accessories. Each dolly is equipped with a low horsepower gasoline engine, an air compressor and an air receiver. The front dolly is equipped with a drawbar mechanism. The rear dolly is equipped with a push plate.

Figure 9-11, page 9-36 is a photo of an existing 60-ton tank transporter built by Dorsey Trailers Inc. This trailer is a typical example of equipment now being used by the military which could be employed to support the solid motor program. This particular transporter could easily be modified to handle 120-inch segments.

FOR DISCUSSION REFER TO PAGE 9-27

TABLE 9-8

STATE HIGHWAY LIMITATIONS

STATE	HEIGHT		WIDTH		LENGTH		WEIGHT	
	Legal	Permit	Legal	Permit	Legal	Permit	Legal	Permit
Alabama	13'6"	14' +	8'		50'		69,500	111,640
Arizona	13'6"	14' +	8'	20' +	65'	80'	76,800	134,400
Arkansas	13'6"	14' +	8'	20' +	65'	NR	76,800	100,000
California	13'6"	15'	8'4"	11'	65'	80'	76,800	115,000
Colorado	13'6"	16'	8'	14'	65'	NR	75,200	126,000
Connecticut	12'6"	14'	8'6"	**	50'	90'	60,000	120,000
Delaware	13'6"	14' +	8'	10'	60'	60'	73,280	90,000
District of Columbia	12'6"	*	8'	*	50'	80'	65,400	*
Florida	13'6"	14'	8'	12'	55'	85'	73,100	300,000
Georgia	13'6"	14' +	8'	12'	50'	75'	63,280	100,000
Idaho	14'	*	8'	14'	65'	*	73,280	112,000
Illinois	13'6"	14' +	8'	12'	60'	70'	72,000	106,000
Indiana	13'6"	15	8'	12' +	50'	70'	72,000	127,400
Iowa	13'6"	13'10"	8'	12'6"	50'	100'	73,280	90,000
Kansas	13'6"	18'	8'6"	16'6"	50'	126'	73,280	130,000
Kentucky	13'6"	14' +	8'	12'	50'	85'	73,280	120,000
Louisiana	13'6"	13'6" +	8'	14'	60'	90'	86,000	111,640
Maine	12'6"	NR	8'	NR	55'	NR	70,550	159,000
Maryland	12'6"	14' +	8'	8'5"	55'	NR	65,000	
Massachusetts	NR	NR	8'	NR	50'	NR	73,000	127,000
Michigan	13'6"	14' +	8'	NR	55'	NR	111,000	100,000

FOR DISCUSSION REFER TO PAGE 9-27

TABLE 9-8 (CON'T)

STATE HIGHWAY LIMITATIONS

STATE	HEIGHT		WIDTH		LENGTH		WEIGHT	
	Legal	Permit	Legal	Permit	Legal	Permit	Legal	Permit
Minnesota	13'6"	14' +	8'	12'	50'	75'	72,500	106,000
Mississippi	13'6"	14' +	8'	15'6"	45'	75'	64,650	110,000
Missouri	12'6"	14' +	8'	12'	50'	75'	64,650	105,000
Montana	13'6"	18'	8'	15'	60'	70'	76,800	112,000
Nebraska	13'6"	16'	8'	10'	60'	90'	73,250	115,000
Nevada	NR	13'7" +	8'6"	*	NR	NR	76,800	130,000
New Hampshire	13'6"	*	8'	12' +	50'	75'	66,400	140,000
New Jersey	13'6"	NR	8'	NR	50'	70'	73,280	
New Mexico	13'6"	13'6"	8'6"	30'	65'	73'	86,400	11,640
New York	13'	*	8'	14'	50'	NR	65,000	127,400
North Carolina	12'6"	14'	8'	12'	50'	75'	65,100	122,000
North Dakota	13'6"	14' +	8'	10' +	60'	75'	73,280	
Ohio	13'6"	13'6" +	8'	12' +	60'	75'	78,000	143,000
Oklahoma	13'6"	17'6"	8'	12'	50'	80'	73,280	134,000
Oregon	12'6"	14'6"	8'4"	14'	65'	105'	76,000	127,400
Pennsylvania	12'6"	14'	8'	10' +	50'	85'	63,800	120,000
Rhode Island	12'6"	14' +	8'6"	18'	50'	80'	88,000	
South Carolina	13'6"	14' +	8'	9'6"	55'	100'	75,150	70,000
South Dakota	13'6"	NR	8'	10'	60'	NR	73,280	105,000
Tennessee	12'6"	14' +	8'	10'	50'	NR	61,580	
Texas	13'6"	14' +	8'	20'	50'	75'	75,600	100,000

FOR DISCUSSION REFER TO PAGE 9-27

TABLE 9-8 (CON'T)
STATE HIGHWAY LIMITATIONS

STATE	HEIGHT		WIDTH		LENGTH		WEIGHT	
	Legal	Permit	Legal	Permit	Legal	Permit	Legal	Permit
Utah	14'	18'	8'	25'	65'	120'	79,900	130,000
Vermont	12'6"	15'	8'	14'	50'	84'	66,400	100,000
Virginia	13'6"	NR	8'	14' +	50'	80'	70,000	90,000
Washington	13'6"	14'6" +	8'	14' +	65'	141'	72,000	130,000
West Virginia	12'6"	14' +	8'	10'	50'	141'	70,000	110,000
Wisconsin	13'6"	20'	8'	16'	50'	75'	73,000	138,000
Wyoming	13'6"	15'	8'	15'	65'	75'	73,950	105,000

* No Fixed Limit

** Two-thirds of Road Width

FOR DISCUSSION REFER TO PAGE 9-28

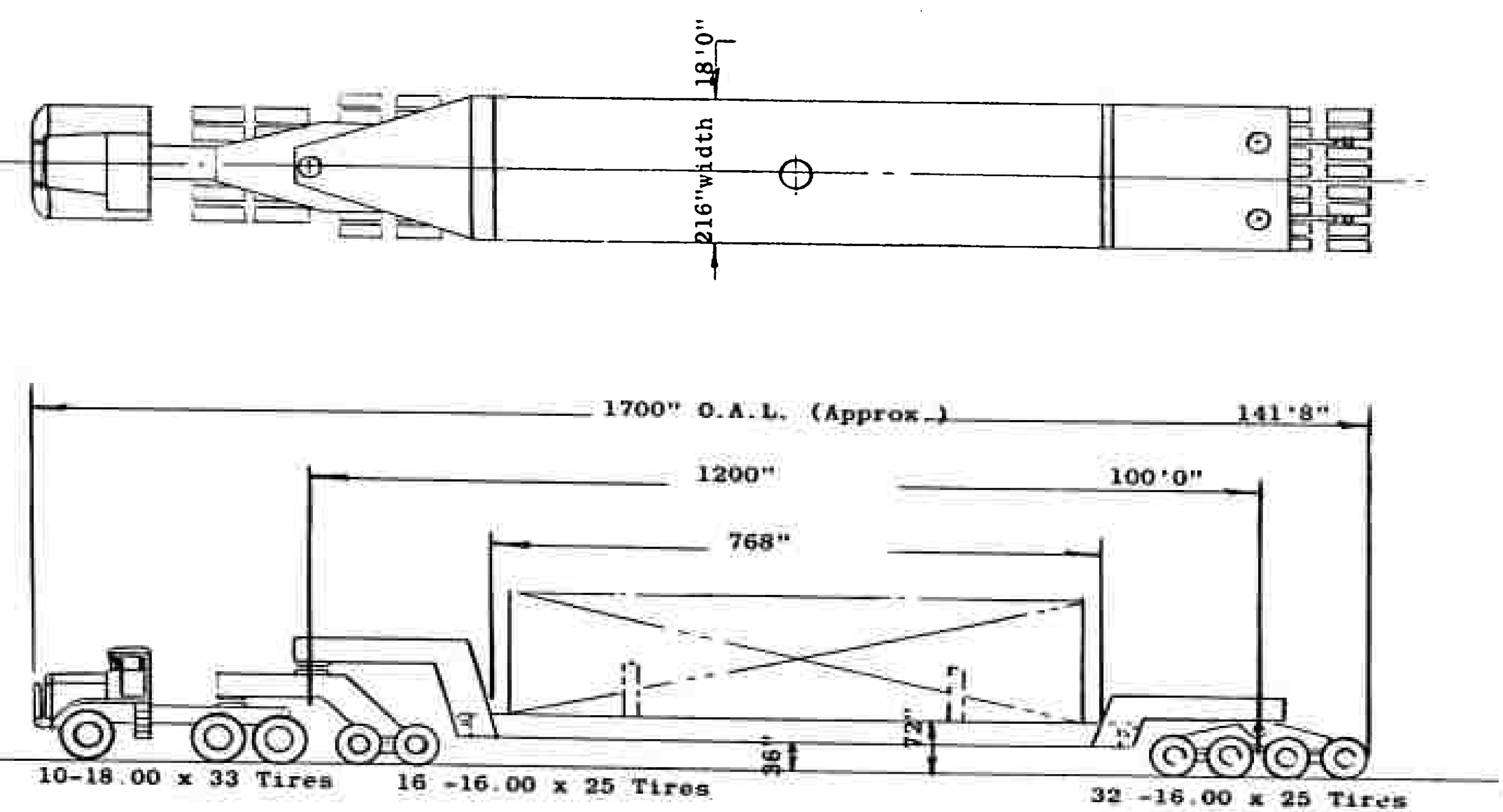


FIGURE 9-8
400 TON CAPACITY TRACTOR TRAILER COMBINATION

(SUPPLIED BY ROGERS BROTHERS CORP.)

FOR DISCUSSION REFER TO PAGE 9-28

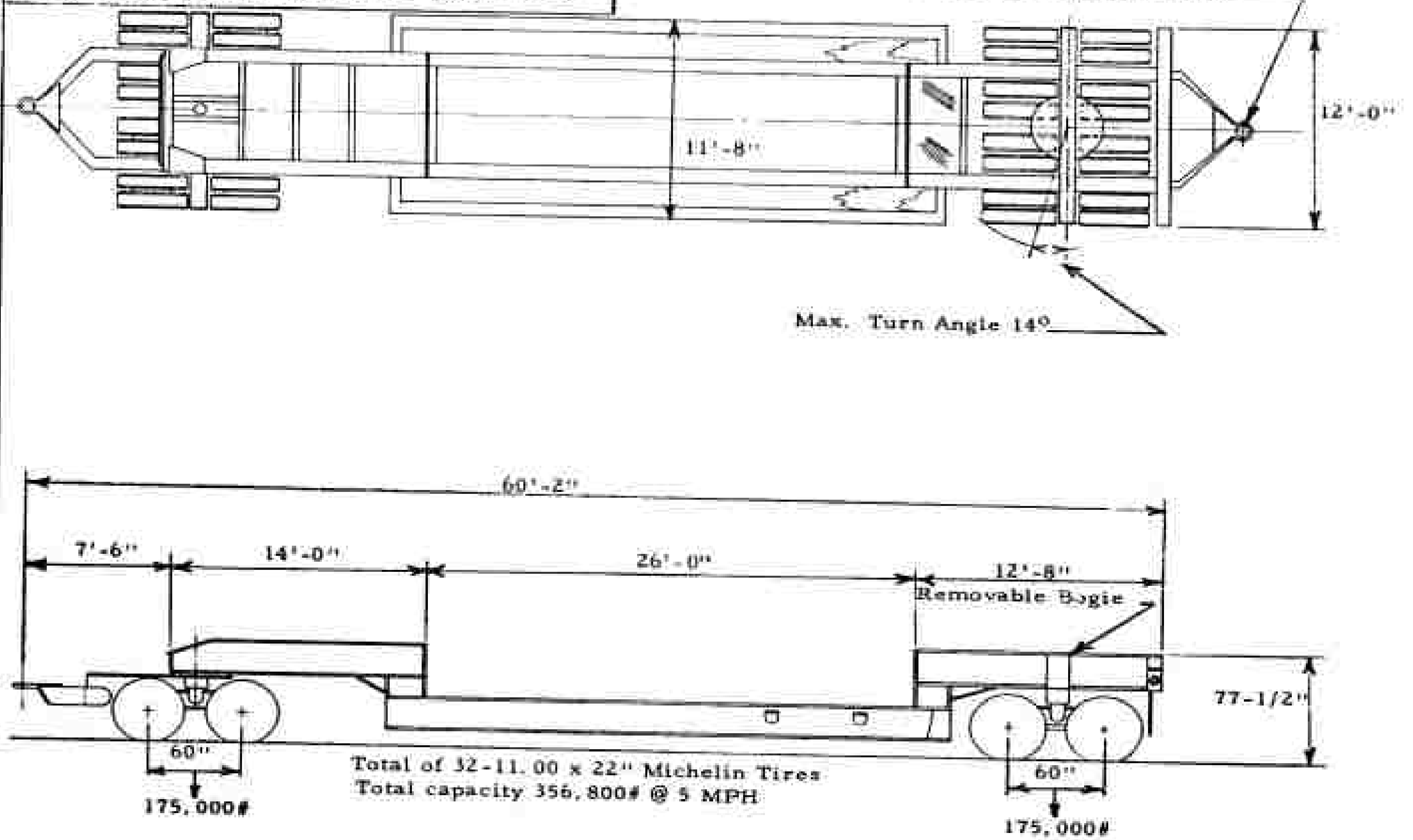


FIGURE 9-9
HIGHWAY TRAILER FOR 350,000 LB. MOTOR SEGMENTS
(SUPPLIED BY GULF ATLANTIC TOWING CORP.)

FOR DISCUSSION REFER TO PAGE 9-29

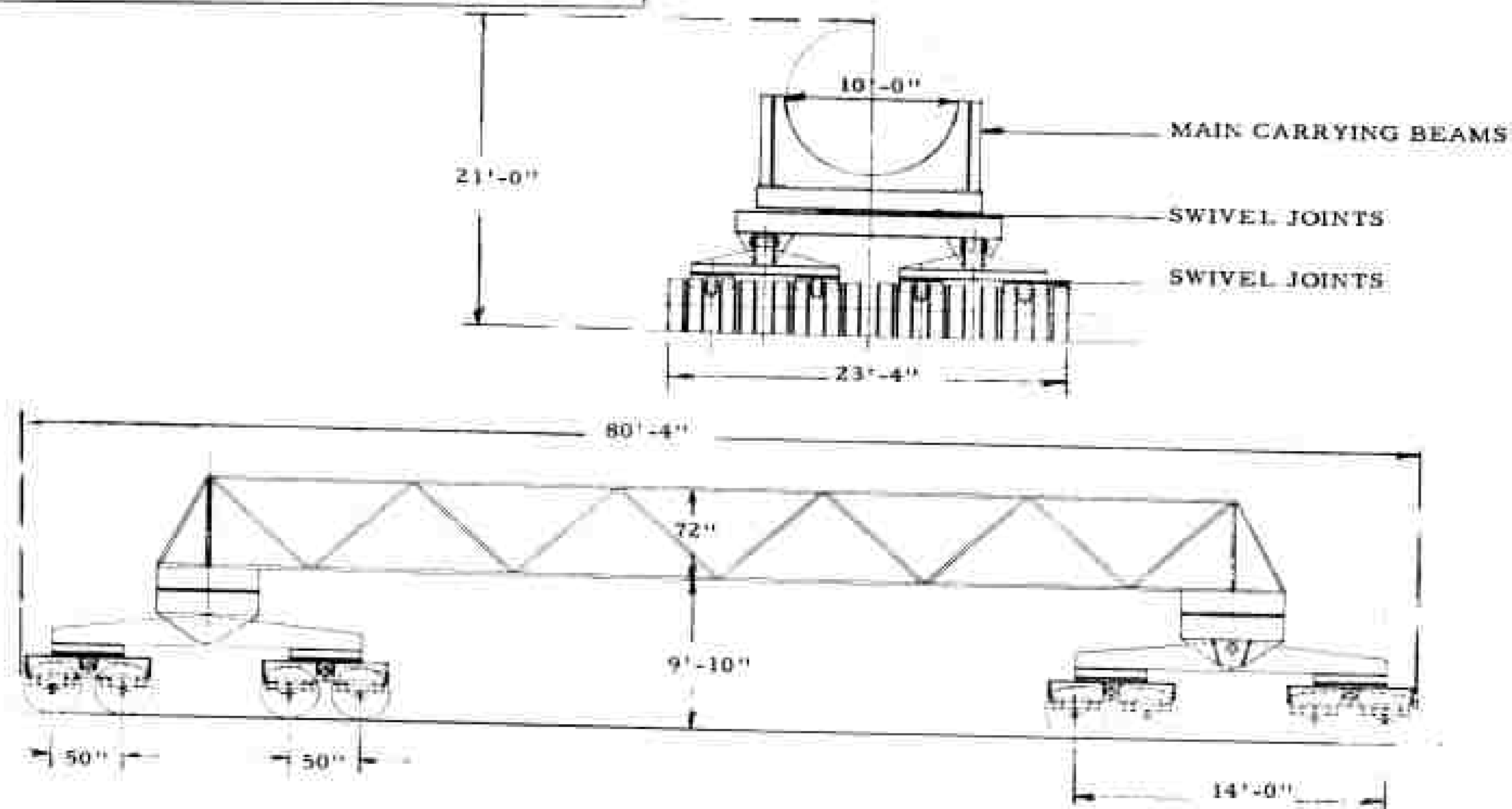


FIGURE 9-10
600 TON MISSILE HAULING TRAILER
(SUPPLIED BY TRAILMOBILE CORP.)

FOR DISCUSSION REFER TO PAGE 9-29

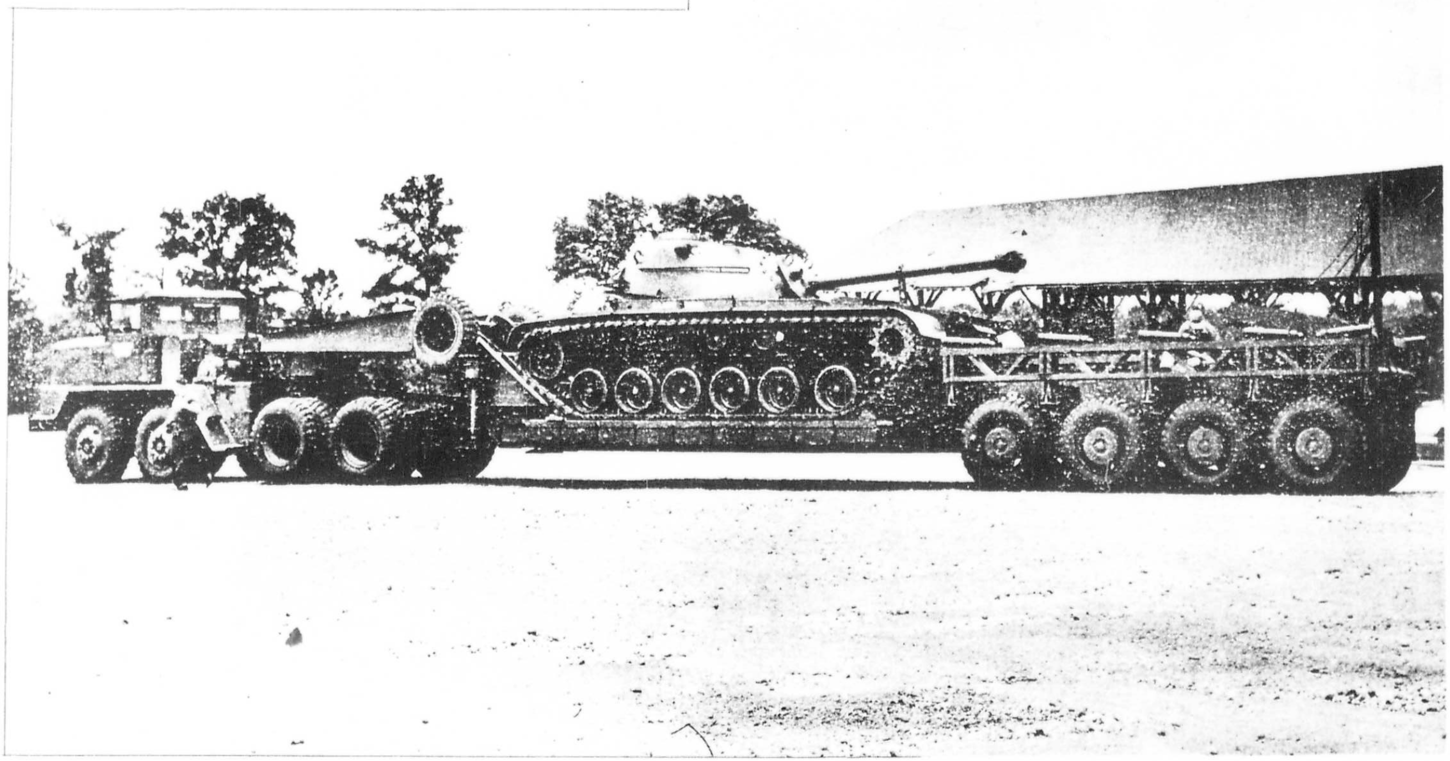


FIGURE 9-11

60 TON TANK TRANSPORTER
(SUPPLIED BY DORSEY TRAILERS INC.)

5. AIR

At present, the equipment available for transporting large, heavy packages by air is limited to the C-133 series aircraft. The maximum cargo capability of the C133-A or B is 100,000 pounds as described in USAF T.O. 01-133A-5. However, flight tests have been performed with cargoes weighing up to 118,000 lbs. The cargo compartments of a majority of these aircraft are approximately 12 ft. x 12 ft.

Rules and regulations pertaining to floor loadings, C.G. of the cargo, unloading, stowage, tiedown, safety and security can also be found in the T.O. referenced above. While this aircraft can probably transport 120-inch diameter segments weighing approximately 100,000 lbs., the cost is prohibitive. Use of the C133 costs approximately $1300 per hour. A round trip between the West Coast and Cape Canaveral would take approximately 20 hours.

An analysis of air transport capabilities for large rocket propulsion systems is given in Technical Documentary Report Nr. ASD-TDR-62-76, dated November 1962, title "Booster Transportation Study". The report is classified as SECRET, however, the title is unclassified.

SECTION 10
INSPECTION

1. GENERAL

Inspection of solid propellant motors requires a combination of several techniques which are available today. Table 10-1, Page 10-4 is a compilation of these techniques, together with their principles of operation, limitations, advantages and applications.

2. ULTRASONIC INSPECTION

The information in Table 10-1, page 10-4 has been compiled from technical papers on the subject. Manufacturers contacted have indicated availability of off-the-shelf inspection systems but were unable to supply pertinent data as to the applicability of their equipment to inspection of solid rocket motors.

3. REMOTE SURFACE INSPECTION

A variety of equipment for visual inspection of remote surfaces is available. Figure 10-1, page 10-5 is a device for examining the interior of rocket motors for flaws, cracks, fissures or other irregularities. It is manufactured by the Keuffel and Esser Company and is known in the trade as a "Corescope". The device sweeps a 360 degree plane as it traverses the longitudinal axis of the rocket motor, thereby permitting visual access to all internal areas.

Other devices for inspecting remote surfaces are generally known as Borescopes. These are manufactured by a number of companies such as: American Cystoscope, Inc., Homestrand, Kollmorgen Optical Co., and Lenox Instrument Co. Existing Borescopes do not have the required length for inspection of large solid motors. It appears, however, that modification of existing instruments to meet the length requirements, should not be too difficult.

4. RADIOGRAPHIC INSPECTION

The radiographic linear accelerator is one of the essential pieces of equipment in use today for inspecting large solid propellant rocket

motors. Figure 10-2, page 10-6, supplied by Applied Radiation Corp., is a typical example of a crane-mounted linear accelerator. A drawback to the use of this particular method of inspection for solid propellant rocket motors is the time consumed. Knowing the propellant thickness and the intensity of the machine being used enables one to determine the time required to make a single exposure. Figure 10-3, page 10-7, supplied by Varian Associates, presents this information in graphical form. With this information and a knowledge of the motor's physical characteristics, the total time for radiographic inspection of a motor can be determined. A preliminary estimate by Thiokol Chemical Corporation yielded the result that inspection of a 260-inch monolithic motor would require approximately 10 days.

Costs of radiographic inspection units vary between 160,000 and 350,000 dollars (exclusive of crane costs). The cost is primarily dependent upon the energy level desired.

Figure 10-4, page 10-8, supplied by Varian Associates, is a 10 MEV radiographic installation at the Naval Ammunition Depot, Concord, California. At this installation, the first stage of the Polaris motor (shown in the figure) is inspected. A list of some of the pertinent specifications for this piece of equipment are shown on the figure.

Examples of concepts for mobile radiographic inspection equipment can be found in Figures 10-5, and 10-6, pages 10-9 and 10-10, supplied by Varian Associates. Figure 10-5, page 10-9 is a concept for a mobile aboveground inspection facility, Figure 10-6, page 10-10 depicts inspection of a large solid motor while it is in a static test pit.

5. INFRARED INSPECTION

Information has been obtained from the Perkin-Elmer Corporation of Norwalk, Connecticut on the application of infrared inspection techniques to solid propellant motors. The technique being investigated by Perkin-Elmer is called Thermal Infrared Inspection (TIRI). The primary aim of this investigation is to provide a highly reliable method of detection and location of flaws at the bond interfaces of the laminate structure making up the rocket casing thermal barrier. The system being studied employs conventional induction heating apparatus and a concentrator coil assembly for continuous injection of heat energy into the elemental adjoining areas of the specimen, with subsequent radiometer measurement from the heated region. An important feature of the technique permits segregation of the

defects by interface, location or depth, through the application of the exposure-time principle, (that is: defects in different layers can be distinguished by varying the exposure times. This can be easily accomplished by providing a number of detection units).

The inspection rate for this technique is limited primarily by the power output available from the RF induction generator; one square foot per minute is readily achieved at an injection level of about 1000 watts.

The Rocket Propulsion Laboratory has an effort under Contract AF 04(611)-8391 to Atlantic Research Corporation, Alexandria, Virginia, entitled "A Feasibility Study for Non-Destruct Testing of Solid Propellants". Among the various techniques under consideration is the potential of attenuated total reflection using an infra-red light source. The program was still underway at the time of publication of this report and sufficient details were not available for inclusion. Information can be obtained regarding the effort by contacting the Rocket Propulsion Laboratory (DGRPW), Edwards, California.

FOR DISCUSSION REFER TO PAGE 10-1

TABLE 10-1

APPLICATION OF NON-DESTRUCTIVE TESTING METHODS TO SOLID MOTORS

METHOD	PRINCIPLE OF OPERATION	USE	LIMITATIONS	ADVANTAGES	APPLICATIONS
ULTRASONIC	Vibrations above 200,000 cps are introduced into sample. Waves are reflected or scattered by discontinuities	Quality Control. Material Inspection. Preventive maintenance.	Sensitivity is reduced by rough-surfaced parts. Odd-shaped pieces are hard to analyze. Requires skilled operator.	Locates smallest discontinuities: Cracks 2×10^5 inches thick at center of 30-in. section. Locates lack of bonding: Areas 1/32-in. diameter or 1/16-in. below surface. Accurate to half the wave-length of used frequency. Locates subsurface defects.	Determination of separation between insulation and case. Determination of separation between liner and case.
	Resonance systems: Frequency varied When natural frequency of material is hit, amplitude of vibration increases.	Thickness measurement. Discovering laminar defects and corrosion wall-thinning.	Works best on parts with parallel sides.		
	Pulse-Echo: Frequency constant for a very short pulse. The bounced-back (echo) pulse is accurately timed, indicating depth.	Locating casting inclusions, internal ruptures, poor welds.	Requires well-trained and experienced operator to evaluate signals.		
REMOTE SURFACE	Examination of inaccessible surfaces with special devices, i.e., borescopes, replica probes, panoramic cameras, fiber optics.	Visual examination of hidden surfaces.	Will detect only defects visible to the eye. Cannot find buried defects.	Permits examination of hidden surfaces.	Cracks or voids on surface of propellant grain.
RADIATION	Penetrating rays (x-ray or gamma) cast shadows on the other side of "solid" objects. Voids permit more rays to penetrate. Film radiography records shadow on photographic film. Fluoroscopy records shadow on fluorescent screen.	Manufacturing. Quality control Preventive maintenance. Weld inspection. Finding foreign objects in packaged goods. Geometric details of enclosed surfaces. Thickness gauging.	Economic limit to depth penetration. Hazardous operation. Not sensitive to defects less than 2% thickness of total metal. Complex shapes are difficult to analyze.	Permits visual analysis of buried defects.	Determination of cracks or voids within the propellant. Determination of separation between liner & propellant crane. Determination of separation between insulation and case Determination of separation between liner and case.
INFRARED	Material tested is heated or cooled in some manner. During this operation the material is scanned with an infrared radiation detector to determine the differences in intensity of radiation at the surface.	Location of laminar defects. Determination of near surface flaws.	Cannot find buried defects. Requires a thorough understanding of heat transfer in the material order investigation.	Simple, inexpensive equipment.	Determination of separation between liner and case. Determination of near surface flaws.

FOR DISCUSSION REFER TO PAGE 10-1

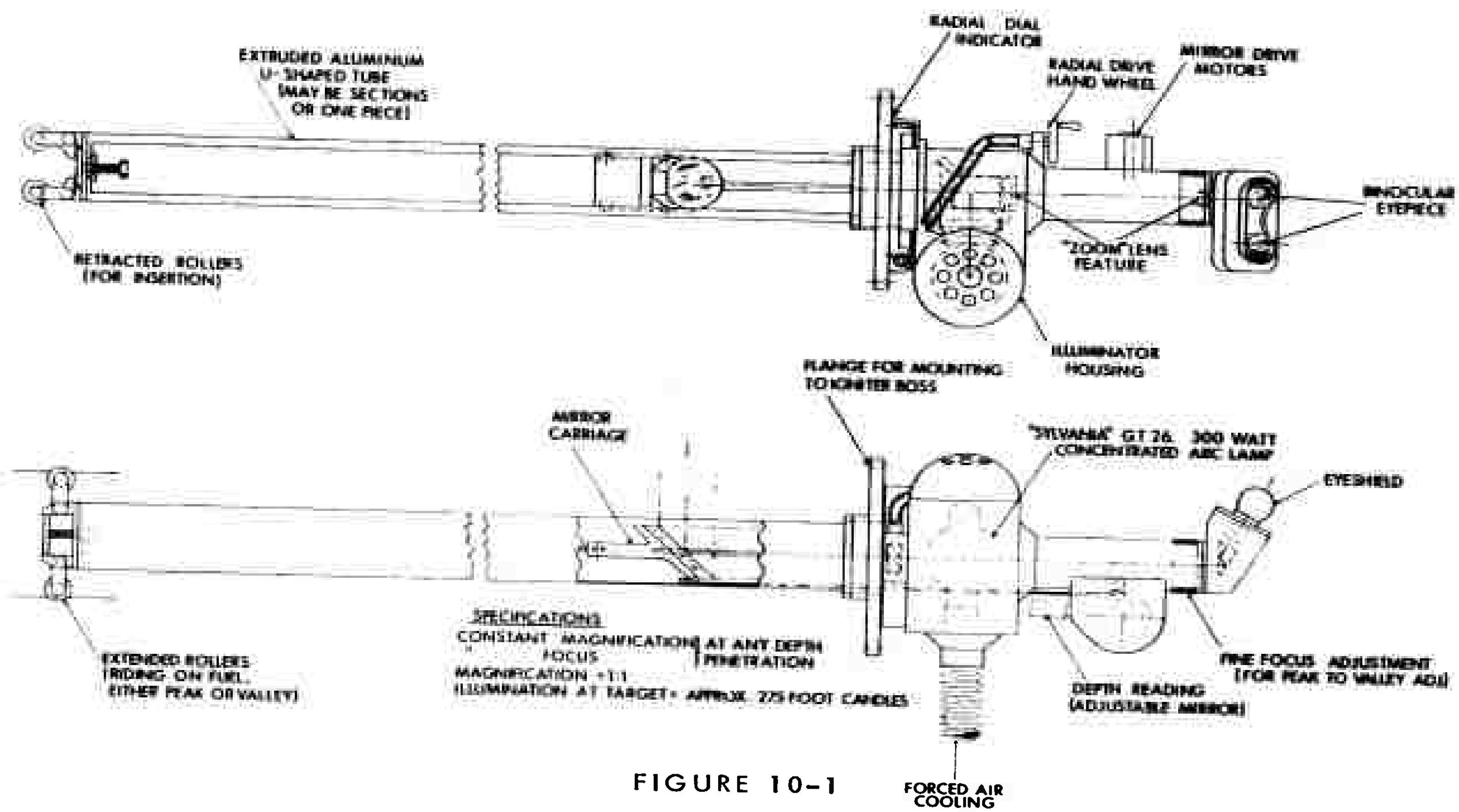


FIGURE 10-1

REMOTE SURFACE INSPECTION
(CORESCOPE)
(SUPPLIED BY KEUFFEL AND ESSER CO.)

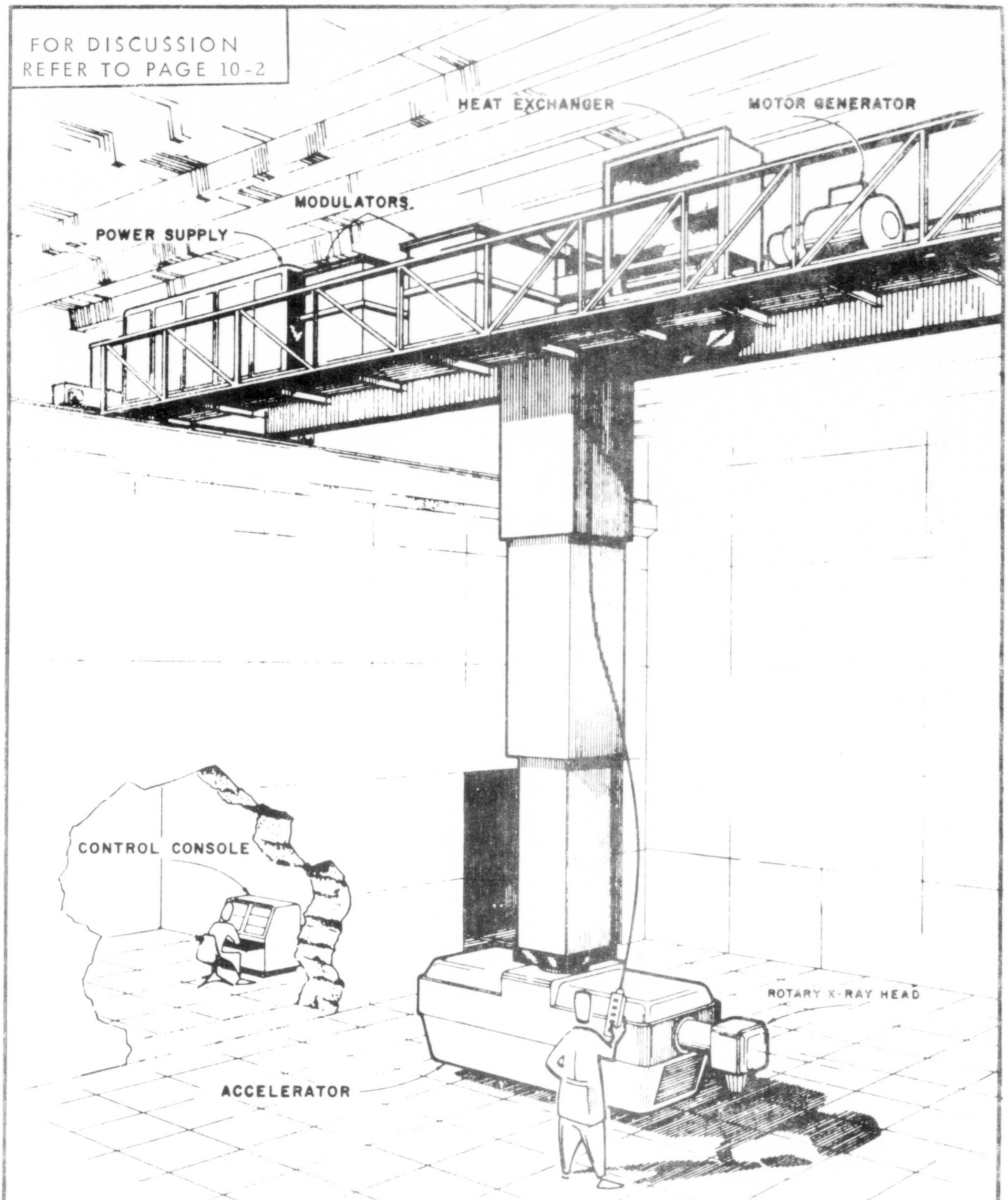


FIGURE 10-2

TYPICAL 8-15 MEV CRANE MOUNTED RADIOGRAPHIC LINEAR ACCELERATOR

(SUPPLIED BY APPLIED RADIATION INC.)

FOR DISCUSSION REFER TO PAGE 10-2

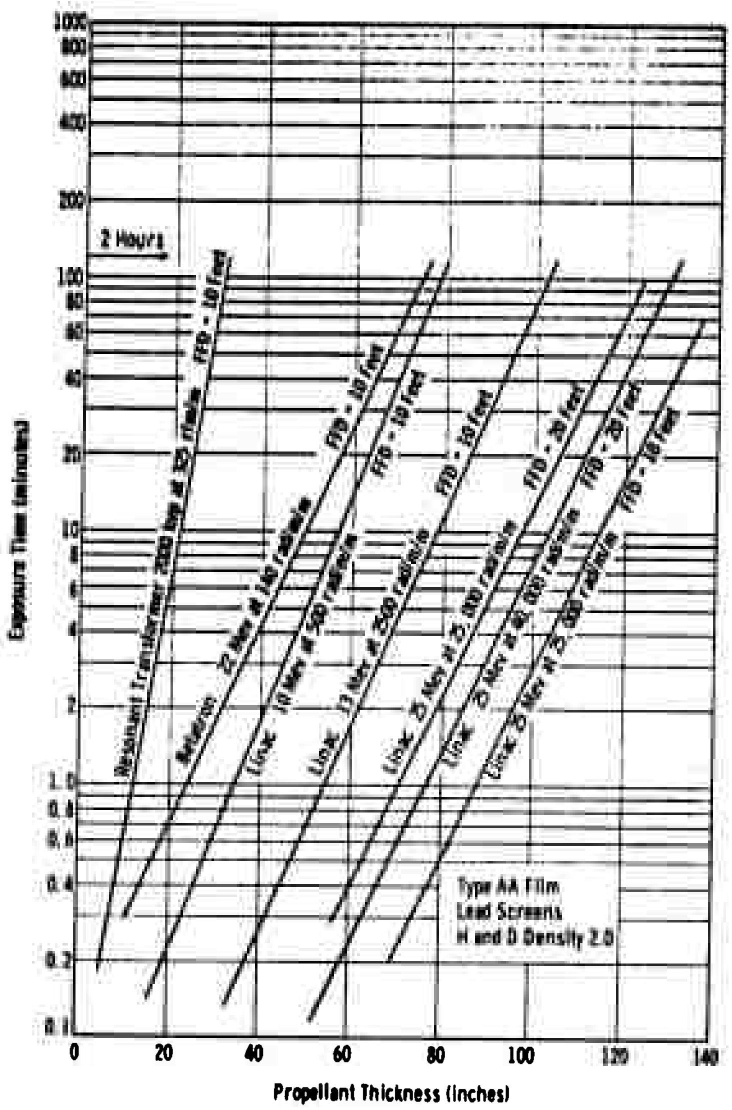


FIGURE 10-3

TYPICAL EXPOSURE CURVES FOR PROPELLANT
(SUPPLIED BY VARIAN ASSOCIATES INC.)

FOR DISCUSSION REFER TO PAGE 10-2

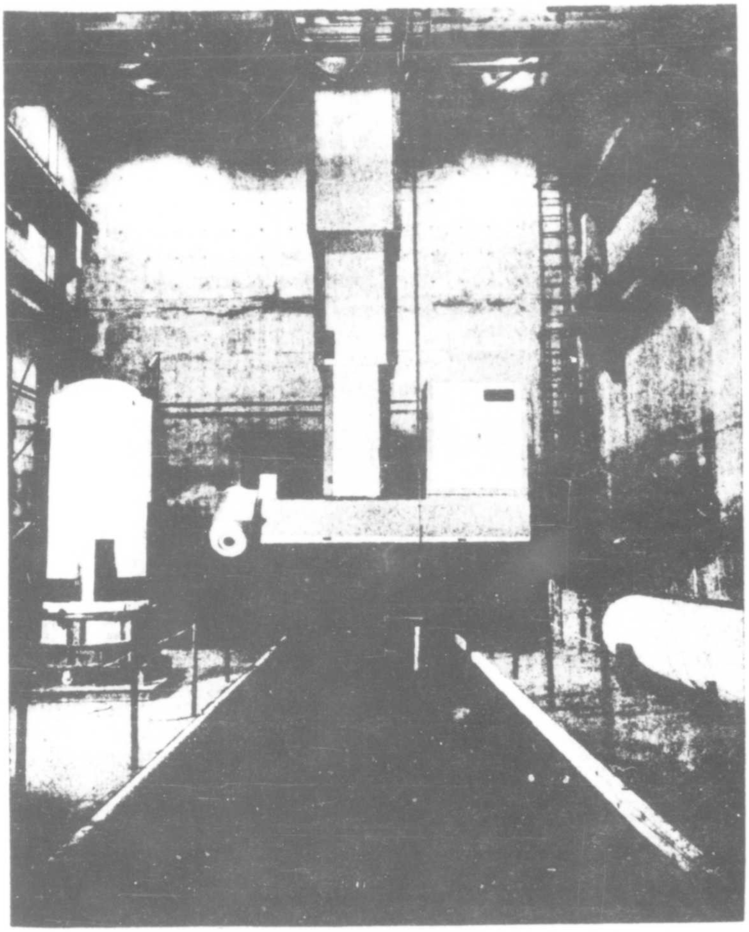


FIGURE 10-4

10 MEV RADIOGRAPHIC INSPECTION FACILITY
(SUPPLIED BY VARIAN ASSOCIATES)

Design Specifications

Beam Energy - MEV rated 10, Minimum 3, Maximum 12.5
X-Ray Output - Central Axis 500, Rads/Min/Meter
Focal Spot (Maximum 1 MM)
The X-Ray head has a provision for directing the beam at any angle between 0 and 360 degrees in the vertical plane without changing the vertical or horizontal position of the focal spot more than 1 cm.
The trolley - telescoping hoist- turntable assembly for suspension of the X-Ray generator is rated as follows:
Hoist capacity 6 tons Min. Crane capacity 7.5 tons Min.

FOR DISCUSSION REFER TO PAGE 10-2

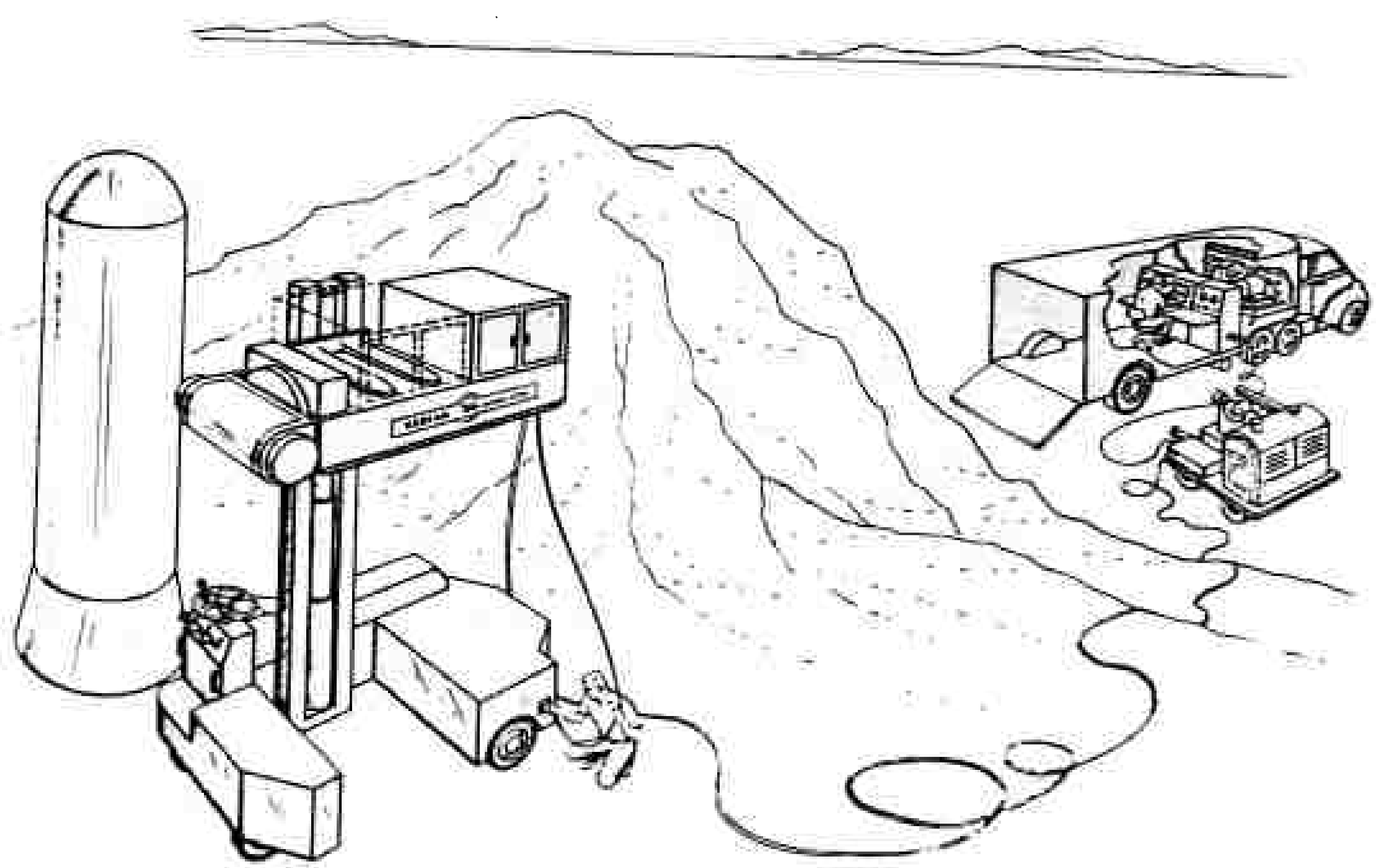


FIGURE 10-5
MOBILE RADIOGRAPHIC UNIT FOR FIELD RADIOGRAPHY
(SUPPLIED BY VARIAN ASSOCIATES INC.)

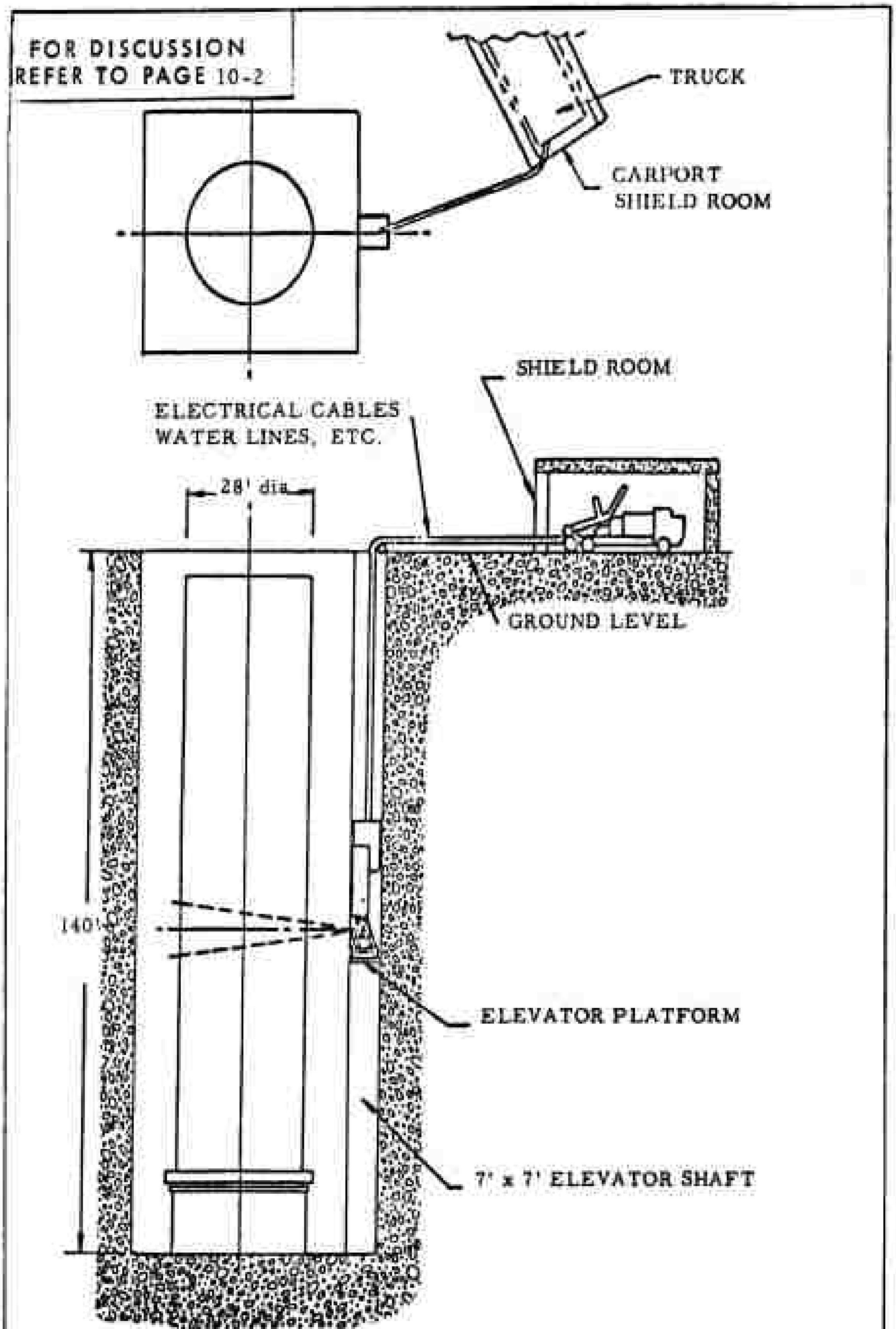


FIGURE 10-6

IN-SILO RADIOGRAPHIC INSPECTION

(SUPPLIED BY VARIAN ASSOCIATES INC.)

SECTION 11
EVALUATION OF HANDLING CONCEPTS

1. GENERAL

This section discusses evaluation of handling concepts for the solid propellant motors covered in this study.

a. 120/156-inch Segmented Motors.

As the study progressed, the handling procedures for the 624A system (120-inch segmented solid motors) were defined by the Air Force and United Technology Center (UTC) (the Air Force's contractor for the solid motors to be used for the 624A system). In view of the fact that UTC was also AMF's subcontractor on this study, their handling procedures were accepted as the optimum for the 120-inch segmented motors. Further, since the 156-inch motors will be similar, the handling procedure established was considered optimum for the 156-inch motors as well.

b. 260-inch Monolithic Motor.

An evaluation was made of the manufacturing/static test facility for the 260-inch monolithic motor. Based on this evaluation it appears that the aboveground CG pivot concept is the best. It is pointed out, however, that this evaluation is strongly dependent on the weighting factor assigned to each evaluation parameter and that a change in these values may alter the conclusion reached.

Optimization of the entire 260-inch system requires additional study of concepts and a definition of ground rules. No conclusions as to the best system can be drawn at this time.

Considerable thought was given to the handling of 260-inch motors at the launch site. In view of the many ground rules and evaluation parameters which must be firmed up, however, an optimum handling concept cannot be definitized at this time.

2. CONCEPT EVALUATION – 260-INCH UNITIZED MOTOR MANUFACTURING/STATIC TEST FACILITY

An objective comparison of Manufacturing/Static Test Facility schemes was performed. Engineering judgement and experience was used to rate each of the various concepts with reference to a set of evaluation parameters established for this comparison. As noted previously, the use of a different set of evaluation parameters and weighing factors could alter the evaluation results considerably.

a. Method of Evaluation.

The Evaluation Procedure consisted of the selection of comparison parameters and assigning weighted values based on a judgement as to their importance. Each Facility Concept was then judged by these "standards".

(1) Comparison Parameters.

NOTE: It should be pointed out that selection of Manufacturing/Static Test Facility for the 260-inch motor is heavily dependent upon the type of operation envisioned for the launch site. The equipment developed for the Manufacturing/Static Test site should be compatible with that to be used for erection and clustering at the launch site so that development and equipment costs are minimized. At the time of publication of this report, it was not possible to establish an optimum launch site handling procedure. This very important parameter has therefore not been included in the evaluation. Further discussion of this point can be found in succeeding pages of this Section.

The following parameters were selected for use in evaluation of the concepts:

1) Reliability
2) Development Risk
3) Operational Complexity
4) Controlability
5) Maintainability
6) Cost
7) Growth Capability

A definition of these parameters as they apply to this evaluation can be found below.

(a) Reliability.

The ability of the proposed concept to function as designed during repetitive use and after periods of idleness, without requiring service or maintenance. The ability to resist malfunction or breakdown.

(b) Development Risk.

The degree of success expected in an R&D program. For example, concepts containing components and systems that have been operated successively in similar applications are considered to provide a smaller risk than those concepts using relatively untried schemes.

(c) Operational Complexity.

The number of operations required and the intricacy of the operational procedure.

(d) Controlability.

The capability of the concept to maintain directional control and stability of the rocket motor throughout the entire handling operation.

(e) Maintainability.

The accessibility of the components and systems and the speeds and procedures required to replace and service critical items.

(f) Cost.

Costs were estimated by either the concept originator or by AMF. They included both the costs of the facility and the associated AGE. Detailed cost data for some of the concepts can be found in Section 5.

Due to the fact that the manufacturing/static test facility must be located near water, the cost of constructing underground facilities is considerably higher than for similar facilities constructed inland. This is due to the nature of the soil in the proximity of ocean waterways.

NOTE: It is pointed out that costs for this type of a facility are difficult to pinpoint since construction estimates may vary by a factor of 2 to 1 depending upon the contractor and the construction method used.

Table 11-1, page 11-7 shows the cost per foot of railway, roadway and canals used in costing out some of the concepts. It is important to note that the canal costs listed bears no relation to the cost of constructing underground pits to depths of 150 feet. The pit costs at this depth are almost an order of magnitude greater than the canal costs.

NOTE: A more complete evaluation of a manufacturing/ static test facility should include operational costs in addition to construction costs. These have not been considered here.

(g) <u>Growth Capability.</u>

The ease of modification to provide for larger and higher thrust rocket motors.

(2) <u>Parameter Weighting Factors.</u>

Weighting factors were assigned to the various parameters on the basis of their assumed relative importance. The weighting factors can vary from a value of 0 to a value of 10, with 10 considered the highest rating. It is pointed out that the specific weighting factor assigned to each evaluation parameter is dependent on the judgement of the evaluator. A change in these factors could affect the final result of the evaluation.

(3) <u>Relative Rating.</u>

The relative rating of each concept reflects its comparative ability to meet the requirements of each of the parameters. The individual parameter's score for a particular concept was arrived at by multiplying the parameter weighting factor and the relative rating. The total score is obtained by adding the individual parameter scores. The concept with the highest total score is considered to be the optimum concept.

b. <u>Dry vs. Wet Concepts.</u>

The results presented in Table 11-2, page 11-8 indicate the superiority of dry handling techniques as compared to the wet. This higher rating stems from the greater reliability, finer control during handling and erection and lower cost of the dry concepts. Costs for constructing locks and underwater facilities are excessive due to the dredging and backfilling required. The use of water to provide buoyancy so as to reduce crane lift capacity requirements sacrifices reliability and control since a measure of

direct contact is lost. In addition, transient rise and fall of the water level may create unusual control problems. The main advantage of the wet concept is its apparent operational simplicity.

(1) Dry Concepts.

The AMF aboveground concept achieved the highest over-all rating based on the following: (See Figure 5-20, page 5-54)

1) In the terrain in which construction of the test sites is contemplated, an aboveground facility appears to be cheaper than one below ground.

2) Water accumulation and maintenance problems in general will be easier to cope with in the aboveground facility.

3) Modification for expansion can be more easily accomplished with an aboveground structure.

4) The possible lower reliability of moving up a grade, which is basic to this concept, has been surmounted by the use of synchronous chain drives. In addition, it would be feasible to mount brakes on the transporter wheels to prevent "running away" in case of a malfunction.

(2) Wet Concepts.

The Frederic R. Harris Co. and AMF wet concepts achieved the highest ratings for wet concepts. The AMF concept has a higher rating in controlability in that the guide rails provide fixed directional control during the time the water level is lowered. On the other hand, the Harris concept uses a craneway which is always in direct physical contact with the upper portion of the rocket motor, as against the cable winch technique used in the AMF concept. The lack of tie-in to the lower end of the rocket motor in the Harris concept decreases its controlability. It is conceivable that a combination of the craneway and guide rail systems would provide the optimum wet technique. (See Figures 5-30 and 5-31, pages 5-64 and 5-65).

FOR DISCUSSION REFER TO PAGE 11-5

TABLE 11-1

ROADBEDS AND CANALS

	LIQUID			SOLID
RAILWAY *	70' 10' RAILS ON CONCRETE $ 223.00/FT.			70' 10' RAILS ON PILE FOUNDATION $ 550.00/FT
ROADWAY *	70' 15' RUBBER TIRES ON CONCRETE $ 210.00/FT.	70' 20' CRAWLER ON BITUMINOUS $ 131.00/FT.		
CANAL	10' 12' 150' OPEN $ 40.00/FT.	10' 12' 10' 130' OPEN / GUIDE RAIL $ 110.00/FT.	10' 12' 130' BULKHEAD $ 140.00/FT.	15' 17' 10' 180' OPEN / GUIDE RAIL $ 140.00/FT.

* RAILWAY AND ROADWAY COSTS INCLUDE 2% RAMP TO LAUNCH DECK

FOR DISCUSSION REFER TO PAGE 11-5

TABLE 11-2

CONCEPT EVALUATION OF 260 - INCH MOTOR MANUFACTURING/STATIC TEST FACILITY

EVALUATION PARAMETER			RELIABILITY	DEVELOPMENT RISK	OPERATIONAL COMPLEXITY	CONTROL-ABILITY	MAINTAIN-ABILITY	ESTIMATED COST	GROWTH CAPABILITY	TOTAL SCORE	RELATIVE RATING
PARAMETER WEIGHT			10	8	7	7	5	5	3		
DRY CONCEPTS	CLEVELAND PNEUMATICS FIGURE 5-23	RELATIVE RATING	7	7	6	8	5	6	7		
		SCORE	70	56	42	56	25	30	21	300	4
	A.M.F. FIGURE 5-20	RELATIVE RATING	8	8	7	8	9	10	9		
		SCORE	80	64	49	56	45	50	27	371	1
	TODD SHIPYARDS FIGURE 5-22 A	RELATIVE RATING	7	7	6	7	6	8	7		
		SCORE	70	56	42	49	30	40	21	308	3
	A.M.F. FIGURE 5-21	RELATIVE RATING	9	8	7	8	8	9	7		
		SCORE	90	64	49	56	40	45	21	365	2
WET CONCEPTS	A. M.F. FIGURE 5-30	RELATIVE RATING	6	8	8	6	6	3	5		
		SCORE	60	64	56	42	30	15	15	282	5
	FREDRICK R. HARRIS FIGURE 5-31 A	RELATIVE RATING	6	8	9	5	6	3	5		
		SCORE	60	64	63	35	30	15	15	282	5
	NEW YORK SHIPBUILDING FIGURE 5-32	RELATIVE RATING	5	5	5	4	5	4	5		
		SCORE	50	40	35	28	25	20	15	213	6

3. EVALUATION OF HANDLING CONCEPTS FOR 260-INCH UNITIZED MOTORS AT THE LAUNCH SITE

a. General.

In the evaluation of concepts applicable to handling the 260-inch unitized motors at the launch site, the following factors will significantly affect over-all system selection.

1) The number of solid propellant motors which will form a booster will have a significant effect on the handling of motors during the clustering operation and therefore on optimum concept selection.

2) The projected launch rate of the vehicle to be considered will affect the type of system (on-pad booster or off-pad booster assembly). While it is possible to project high launch rates with on-pad booster assembly by building multiple pads, recent trends of Integrated Transfer and Launch techniques have shown that a more economical over-all solution to the ground system can be obtained by off-pad assembly of vehicles.

3) The vehicle mission will affect the facilities to a great extent. Missions with extremely critical launch windows (Salvo Launchers) may require multiple pads rather than an ITL system.

Figure 11-1, page 11-13 and Figure 11-8, page 11-20 represent the various posibilities for handling systems of the 260-inch motor at the launch site. Figure 11-1, page 11-13 shows only systems for on-pad assembly of the monolithic solid propellant motors into complete boosters. Figure 11-8, page 11-20 shows off-pad assembly. Figure 11-2 through 11-7, pages 11-14 through 11-19 represent individual charts of each of the systems projected in Figure 11-1, while Figures 11-9 through 11-11, pages 11-21 through 11-23 similarily amplify Figure 11-2.

b. On-Pad Booster Assembly of 260-Inch Motors.

(1) Horizontal Transport/Pad Gantry Erection (Figure 11-2, Page 11-10)

The motor is moved by means of a horizontal transporter similar to

the one projected in Figure 5-39 , page 5-73 to the launch pad, at which time it is erected by means of an auxiliary gantry (Figure 5-39 , page 5-73) and a breakover stand. This gantry will also be used for clustering. It would be possible to use the overhead crane required for payload assembly to the completed vehicle if the additional capacity (3. 5 million pounds) is provided for this crane. However, in view of the high cost entailed in strengthening the gantry to accommodate the extra 2 million pound capacity at a great height (1. 5 million payload capacity), it appears that the auxiliary crane would be much more economical.

The transporter depicted in Figure 5-20, page 5-54 is of the type which will lift the motor off its support points on the barge. As an alternative, a transporter could be sent with the motor on the barge. Determination of the type of transporter to be used must consider operations at the Manufacturing Facility.

(2) Horizontal Transport/Erection-Vertical Transport-Vertical Transporter Clustering (Figure 11-3, page 11-15)

In this concept, the CG pivot type of transporter (Figure 5-20, page 5-54 is envisioned. The auxiliary erection station projected in this figure would be used to place the motors in vertical position on the vertical transporter. This vertical transporter would then be used at the launch pad in clustering the motors to form a complete booster. (Refer to the discussion associated with Figure 5-41, page 5-74 for a description of the clustering technique).

It should be noted that this concept lends itself to a pad design which could operate without any gantry (Clean Pad). This could be done if the upper stages were brought in as an integrated vehicle subassembly. (See Figure 5-41, page 5-74). In view of the fact that the vertical transporter is used for clustering and must maneuver in confined areas, its design and construction costs are somewhat higher than for a transporter which will perform transportation only.

(3) Horizontal Transport/Erection/Vertical Transport/Gantry Clustering (Figure 11-4, page 11-16)

This concept is similar to the one discussed above except that clustering is performed with a gantry at the pad. Obviously, as pointed out previously, the vertical transporter design is more economical. Economies projected must be compared with the cost of the additional gantry required.

(4) Gantry Off-Loading/Vertical Transport/Vertical Transporter Clustering (Figure 11-5, page 11-17)

This concept is similar to the one projected in Figure 11-3, page 11-15, with the change that the motor is off-loaded and placed on the vertical transporter with the aid of a fixed gantry located at the barge off-loading point. In this case the trade-off consideration consists of a comparison between the cost of the gantry and that of the erection facility.

(5) Gantry Off-Loading/Vertical Transport/Gantry Clustering (Figure 11 - 6, page 11-18)

In this concept a stationary gantry at the barge unloading point picks up the motor with the use of suitable trunnion points at the barge itself and places it onto the vertical transporter. Subsequent to arrival at the launch pad, a pad gantry will perform the clustering. Trade-offs with the previous concepts include cost of the two gantries versus cost of the erection facility and the self-clustering vertical transporter.

(6) Moveable Gantry Off-Loading/Clustering (Figure 11 - 7, page 11 - 19)

In this system a moveable gantry of 3 to 4 million pound capacity will perform all operations discussed previously. While on the surface this concept appears to be the least complicated, it should be noted that the cost of a moveable gantry will be very high in view of its associated mechanism and trackage requirements. Figure 5-37, page 5-71 presents an over-all handling concept using this type of gantry.

c. Off-Pad Booster Assembly of 260-Inch Unitized Motors.

(1) General.

The systems projected in Figure 11- 8, page 11-20 assumes that the entire booster will be assembled on a special transporter away from the pad and thence transported to the pad.

Several methods of clustering offf the pad can be envisioned. They include the Modified Todd Concept shown in Figure 5-42, page 5-75 as well as methods using gantries and CG pivot arrangements. The Modified Todd concept appears to lack reliability when compared to some of the others.

It should be noted that in all cases, the assembled booster is transported vertically to the pad. The heavy weight of such a booster (12 to 15 million pounds for a four-motor configuration) will require heavy road foundations where land transport is envisioned. An alternative to this is the transport by canal and shallow barge. Trade-off consideration among these two basic methods of transportation include cost of roadways versus canal, cost of transporter versus barge and their relative stabilities as well as reliability of operation.

(2) Transport Horizontally/Erect & Cluster at Special Facility (Figure 11-9, page 11-21)

This system requires a horizontal transporter, an erection and clustering station and a booster transporter. The erection concept, typical for this system, would be a CG pivot type in conjunction with a turntable or the Modified Todd Concept.

(3) Gantry Off-Loading and Erection onto Booster Transporter (Figure 11-10, page 11-22)

This scheme projects a stationary gantry located at the barge off-loading point which would be used to cluster the individual monolithic motors on a vertical transporter. (See Figure 5-40, page 5-73). The cost of the gantry must be traded-off with concepts similar to the CG pivot and modified Todd Concepts described previously.

(4) Moveable Gantry Off-Loading/Transport/Motor Clustering (Figure 11-11, page 11-23)

The combination of a clustering facility at the barge unloading facility may be undesirable in view of the multiplicity of motors which may have to be handled. It is conceivable therefore that a gantry capable of transporting these motors to an intermediate clustering station has merit. In this fashion, several barges could be unloaded with the same gantry from different docking positions. The trade-offs here consist of the cost of the gantry and the associated trackage with concepts discussed previously.

FOR DISCUSSION REFER TO PAGE 11-9

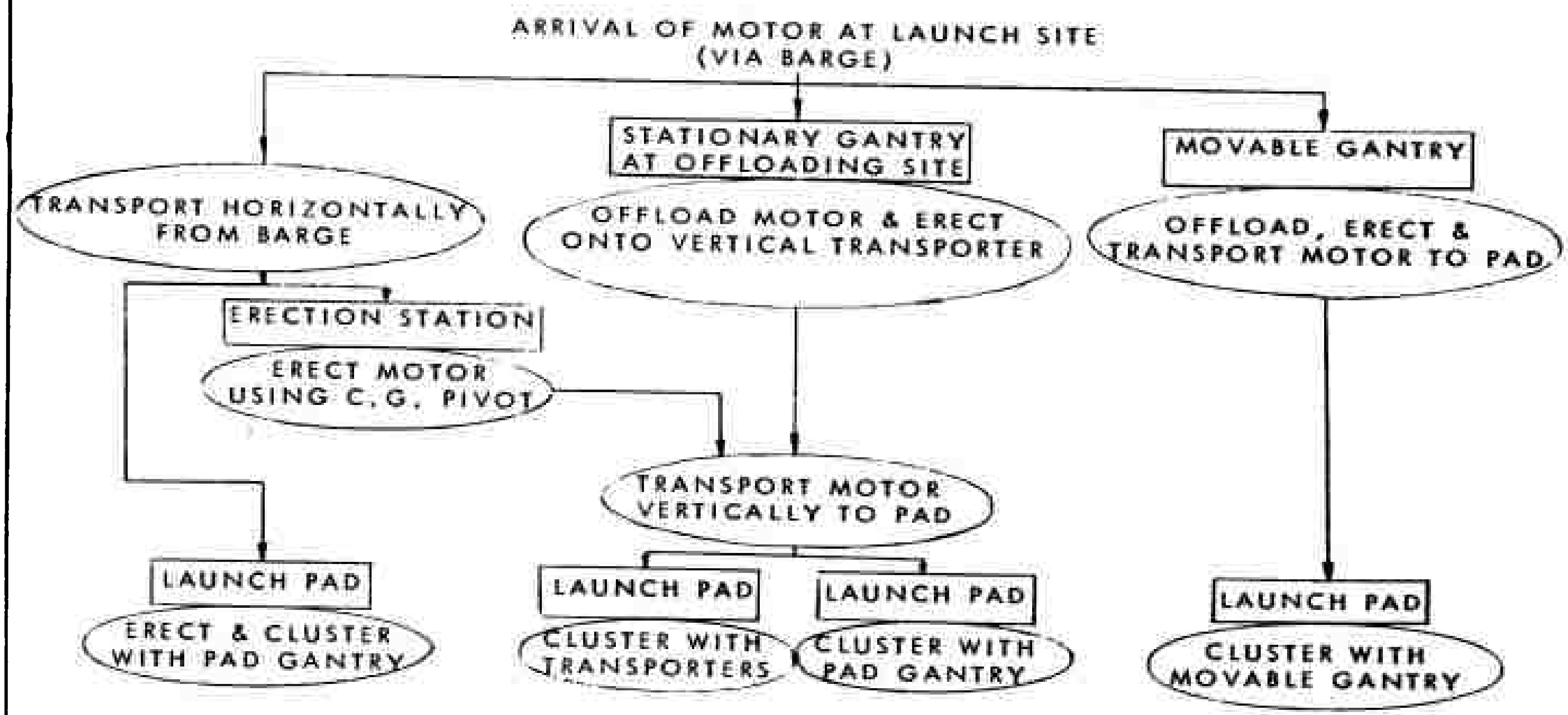
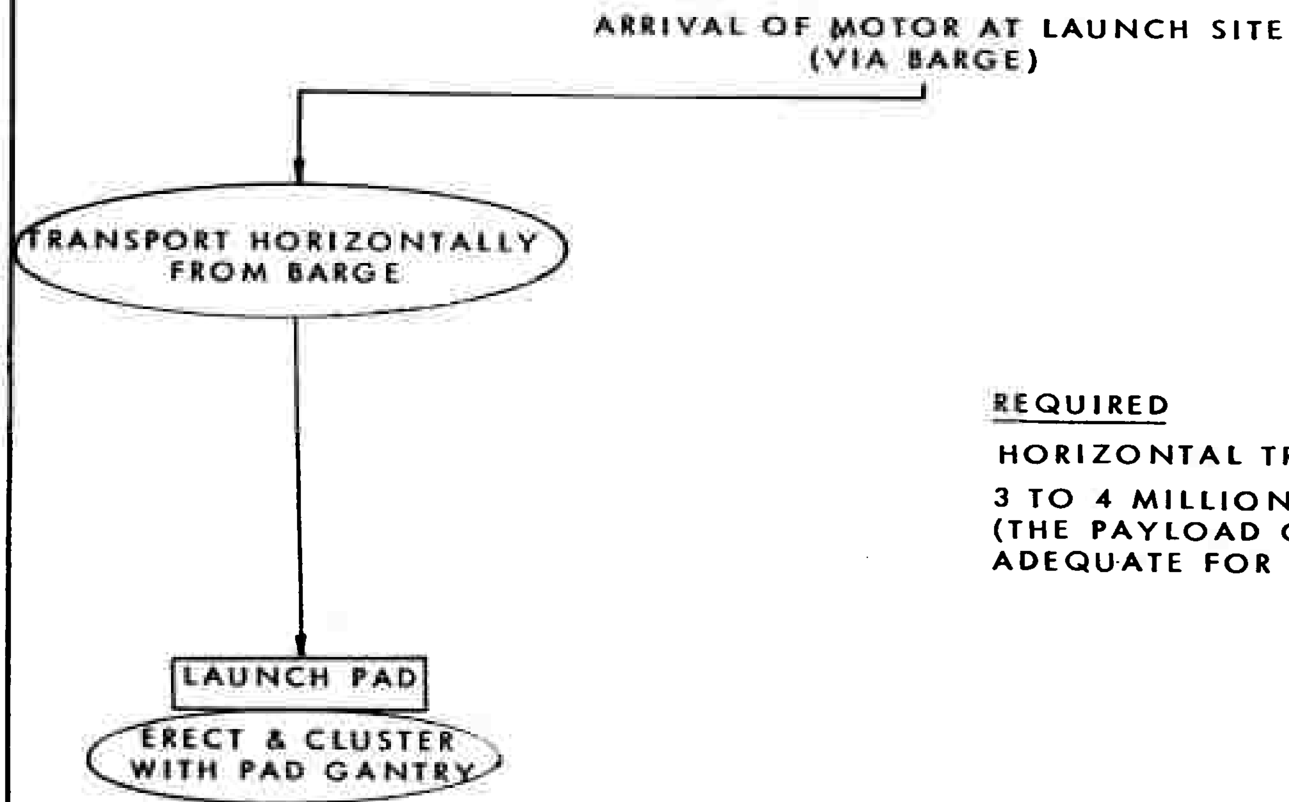


FIGURE 11-1
ON PAD BOOSTER ASSEMBLY OF 260-INCH UNITIZED MOTORS

FOR DISCUSSION REFER TO PAGE 11-9



<u>REQUIRED</u>

HORIZONTAL TRANSPORTER

3 TO 4 MILLION LB. GANTRY AT PAD
(THE PAYLOAD CRANE IS NOT CONSIDERED
ADEQUATE FOR SOLID MOTOR HANDLING)

FIGURE 11-2
ON PAD BOOSTER ASSEMBLY OF 260-INCH UNITIZED MOTORS
(HORIZONTAL TRANSPORT/PAD GANTRY ERECTION)

FOR DISCUSSION REFER TO PAGE 11-10

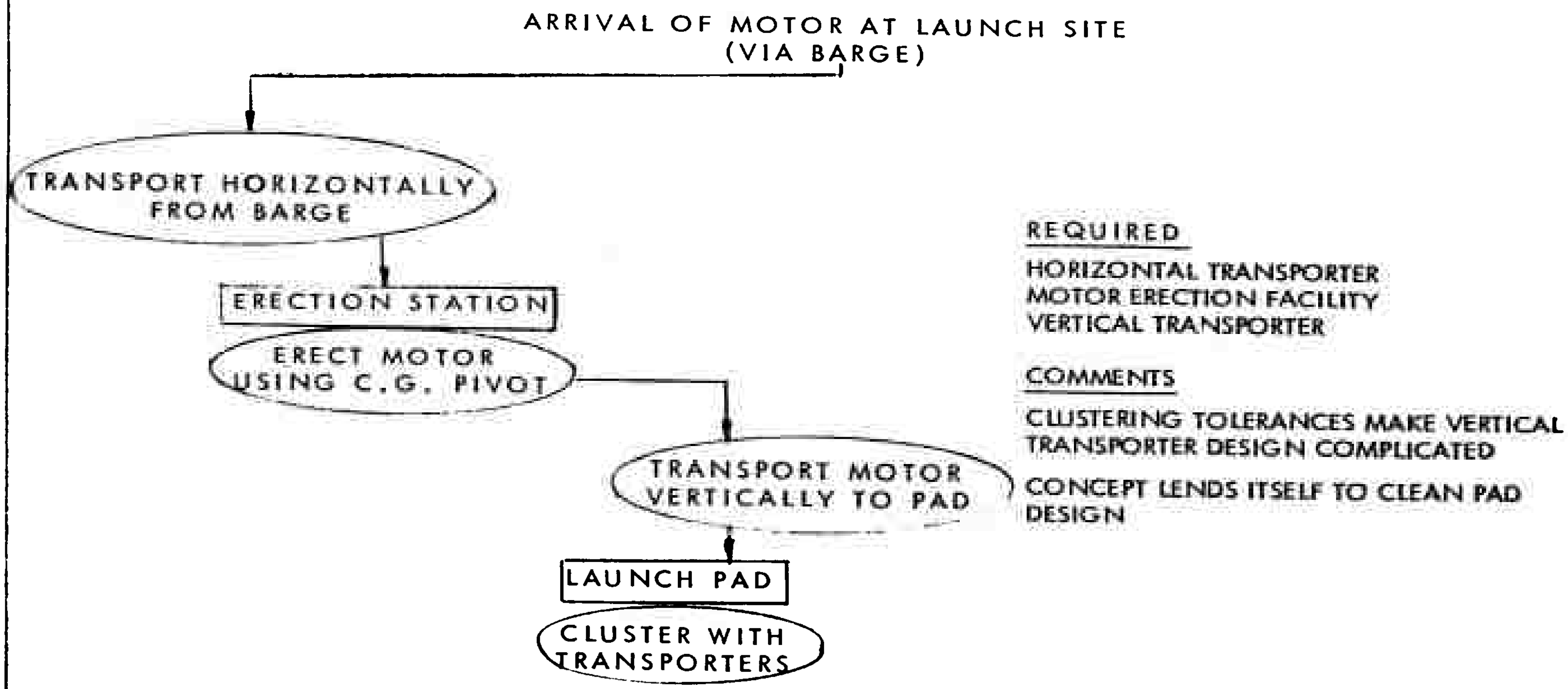
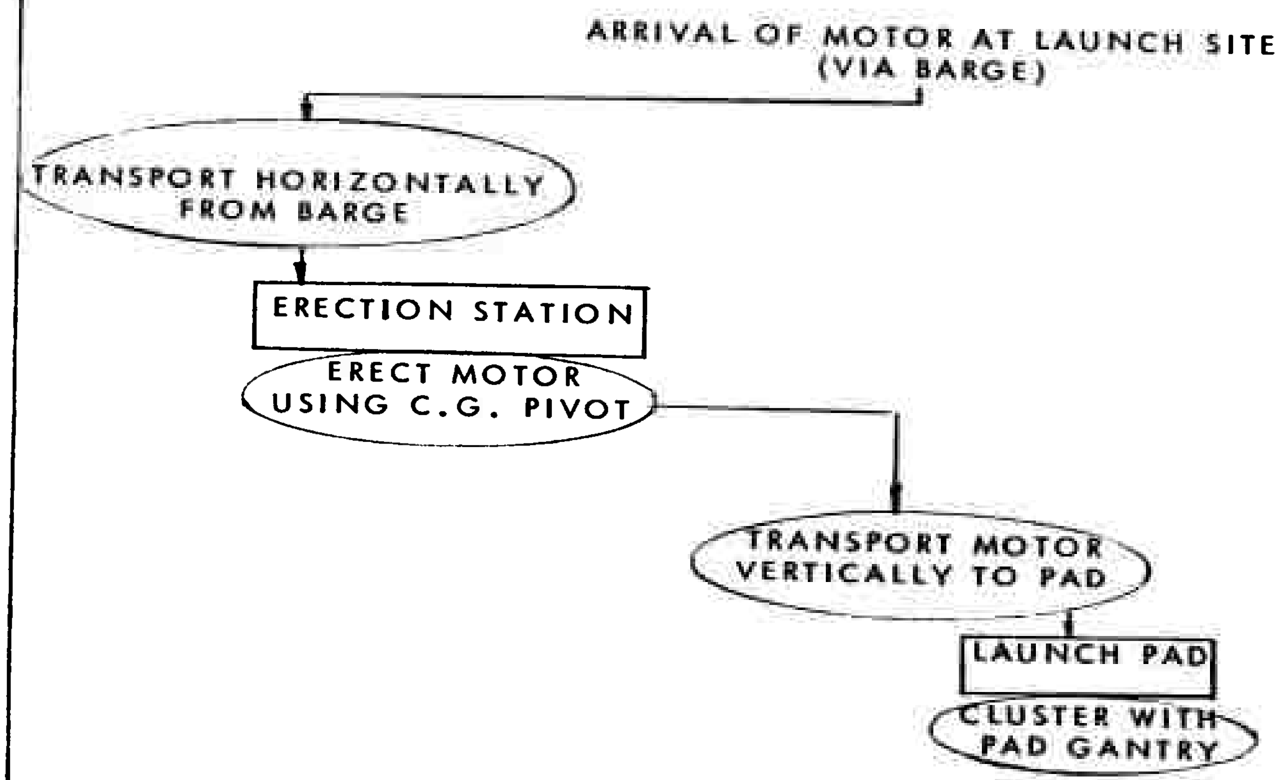


FIGURE 11-3

ON PAD BOOSTER ASSEMBLY OF 260-INCH UNITIZED MOTORS
(HORIZONTAL TRANSPORT/ERECTION/VERTICAL TRANSPORT/VERTICAL TRANSPORTER CLUSTERING)

FOR DISCUSSION REFER TO PAGE 11-10



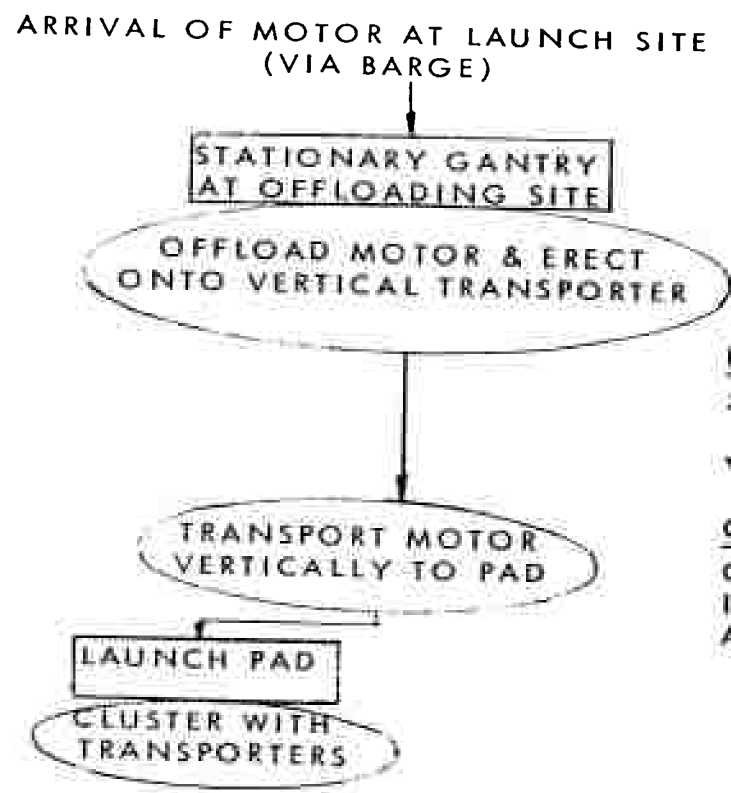
REQUIRED

HORIZONTAL TRANSPORTER
MOTOR ERECTION FACILITY
3 TO 4 MILLION LB. GANTRY
VERTICAL TRANSPORTER

FIGURE 11-4

ON PAD BOOSTER ASSEMBLY OF 260-INCH UNITIZED MOTORS
(HORIZONTAL TRANSPORT/ERECTION/VERTICAL TRANSPORT/PAD GANTRY CLUSTERING)

FOR DISCUSSION REFER TO PAGE 11-11



REQUIRED

3 TO 4 MILLION LB. STATIONARY GANTRY
VERTICAL TRANSPORTER

COMMENTS

CLUSTERING TOLERANCES MAKE VERTICAL TRANSPORTER DESIGN COMPLICATED

FIGURE 11-5

ON PAD BOOSTER ASSEMBLY OF 260-INCH UNITIZED MOTORS
(GANTRY OFFLOADING/VERTICAL TRANSPORT/VERTICAL TRANSPORTER CLUSTERING)

FOR DISCUSSION REFER TO PAGE 11-11

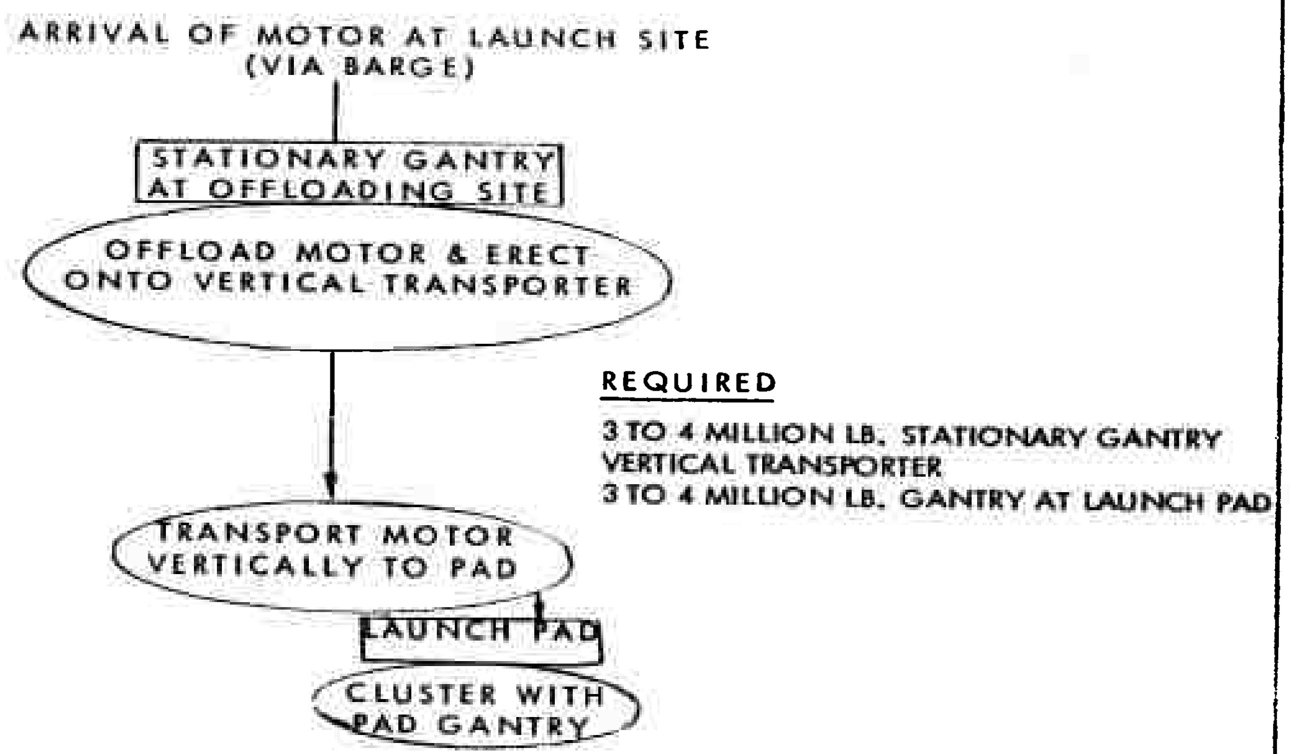
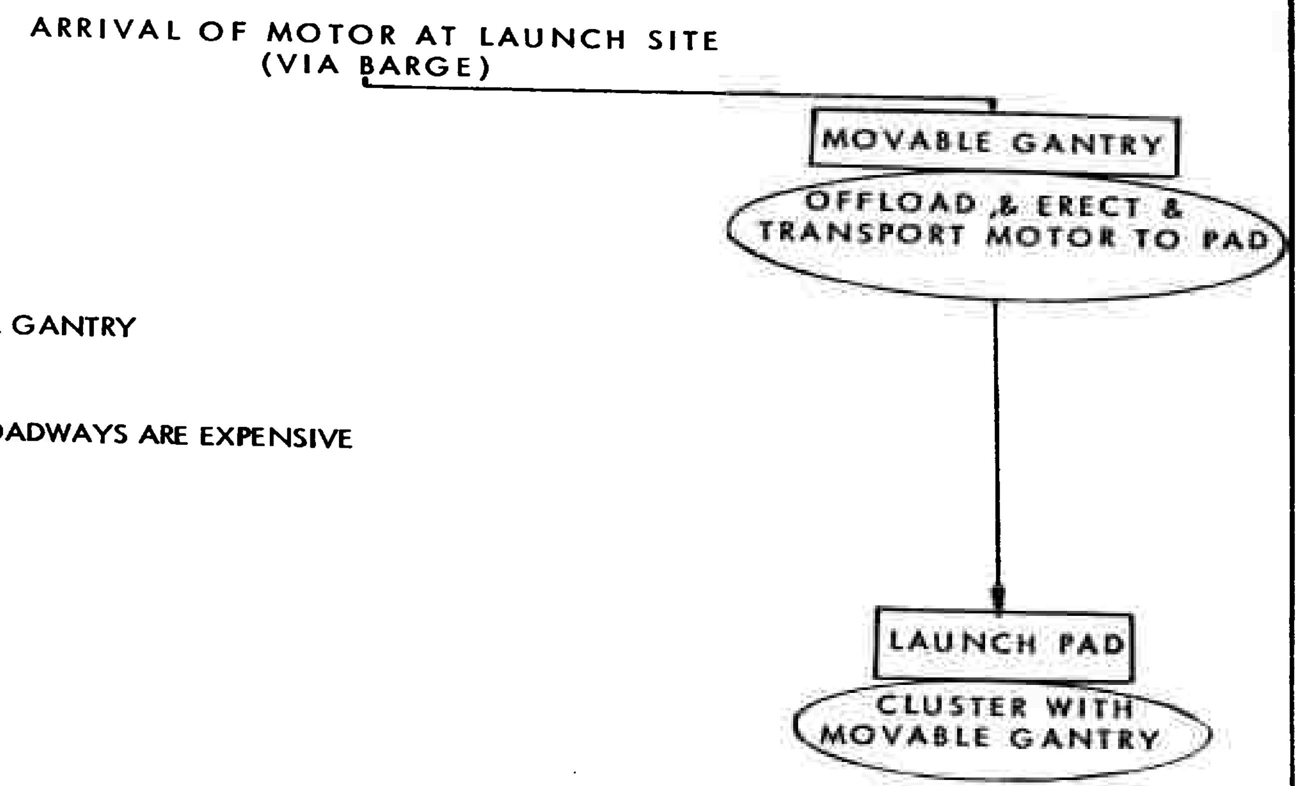


FIGURE 11-6

ON PAD BOOSTER ASSEMBLY OF 260-INCH UNITIZED MOTORS
(GANTRY OFFLOADING/VERTICAL TRANSPORT/PAD GANTRY CLUSTERING)

FOR DISCUSSION REFER TO PAGE 11-11



REQUIRED

3 TO 4 MILLION LB. MOVABLE GANTRY

COMMENT

GANTRY AND ASSOCIATED ROADWAYS ARE EXPENSIVE

FIGURE 11-7

ON PAD BOOSTER ASSEMBLY OF 260 - INCH UNITIZED MOTORS
(MOVABLE GANTRY OFFLOADING, TRANSPORTING & CLUSTERING)

FOR DISCUSSION REFER TO PAGE 11-11

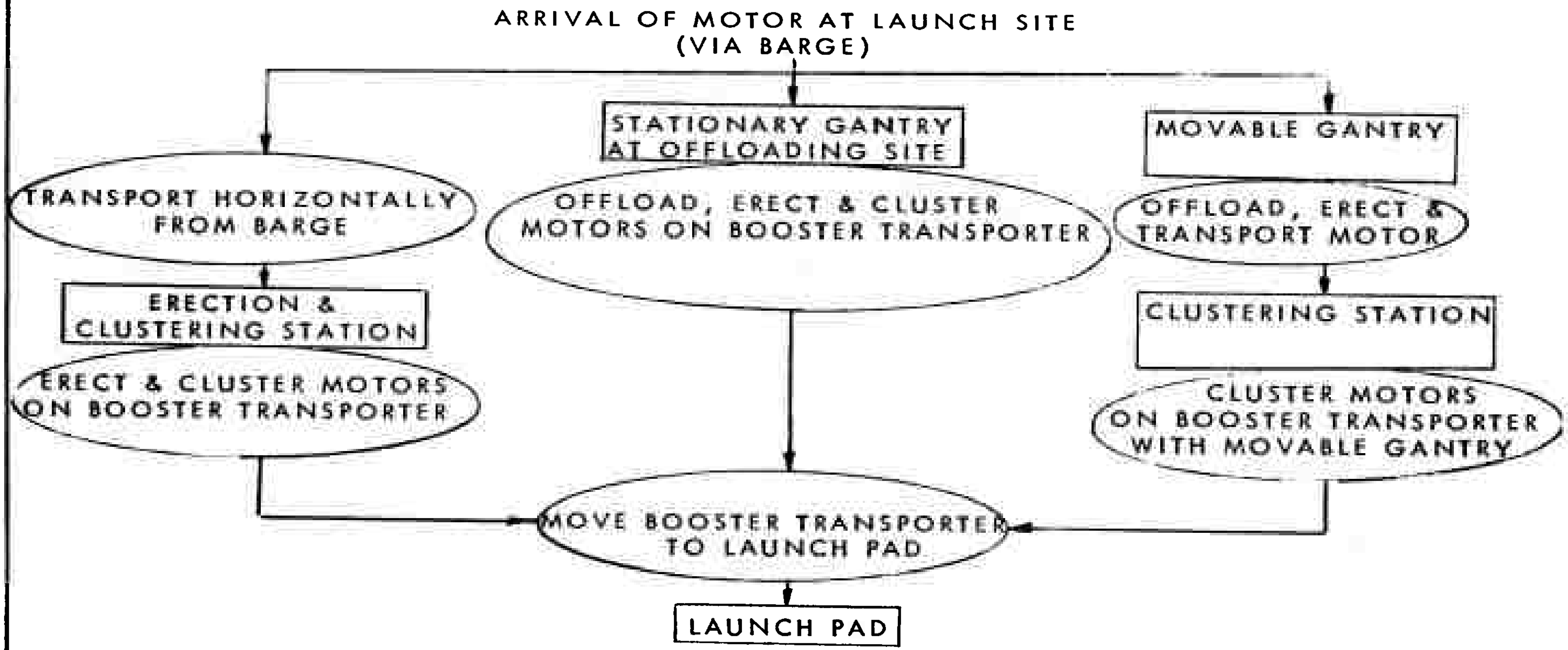
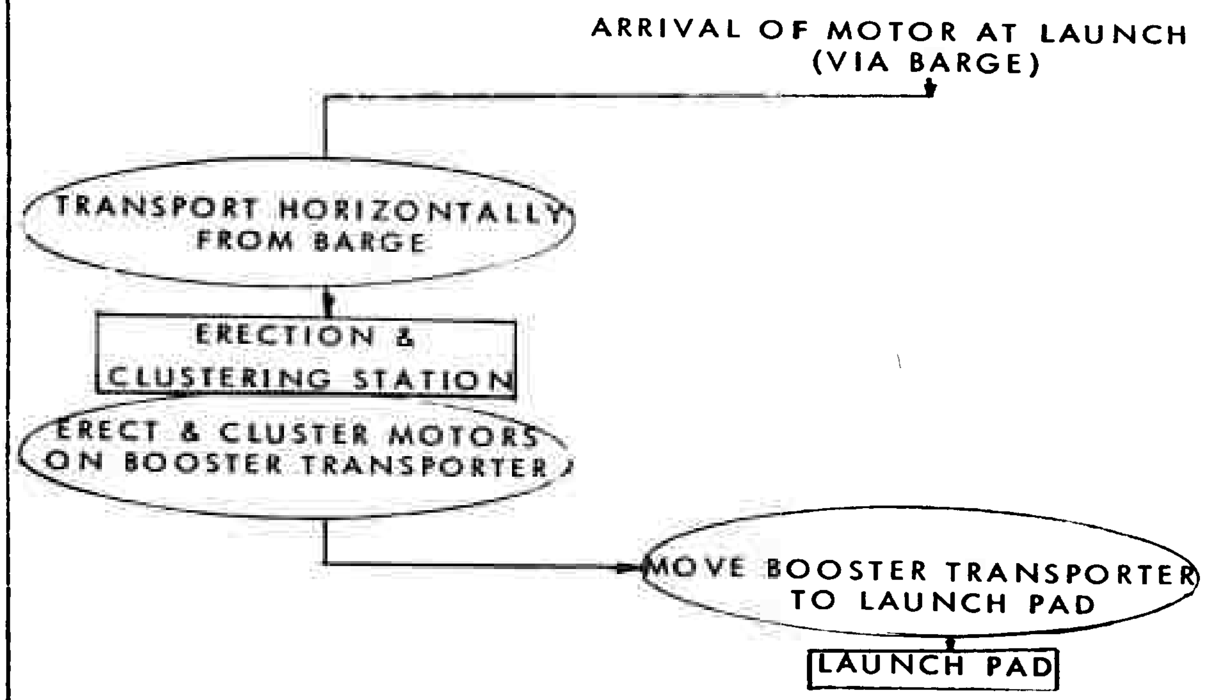


FIGURE 11-8

OFF PAD BOOSTER ASSEMBLY OF 260 - INCH UNITIZED MOTORS

FOR DISCUSSION REFER TO PAGE 11-12



REQUIRED

HORIZONTAL TRANSPORTER
ERECTION & CLUSTERING STATION
BOOSTER TRANSPORTER

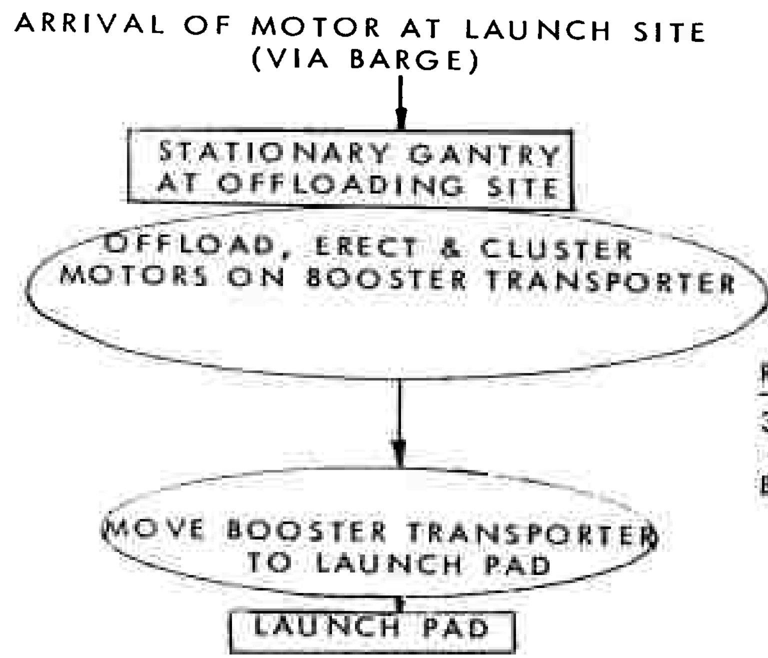
COMMENT

BOOSTER TRANSPORTER REQUIRES HEAVY ROADWAY FOUNDATION

FIGURE 11-9

OFF PAD BOOSTER ASSEMBLY OF 260 - INCH UNITIZED MOTORS
(TRANSPORT HORIZONTALLY/ERECT & CLUSTER AT SPECIAL FACILITY)

FOR DISCUSSION REFER TO PAGE 11-12



REQUIRED

3 TO 4 MILLION LB. STATIONARY
GANTRY
BOOSTER TRANSPORTER

FIGURE 11-10

OFF PAD BOOSTER ASSEMBLY OF 260 - INCH UNITIZED MOTORS
(GANTRY OFFLOADING & ERECTION ONTO BOOSTER TRANSPORTER)

FOR DISCUSSION REFER TO PAGE 11-12

REQUIRED

3 TO 4 MILLION LB. MOVABLE GANTRY
CLUSTERING STATION
BOOSTER TRANSPORTER

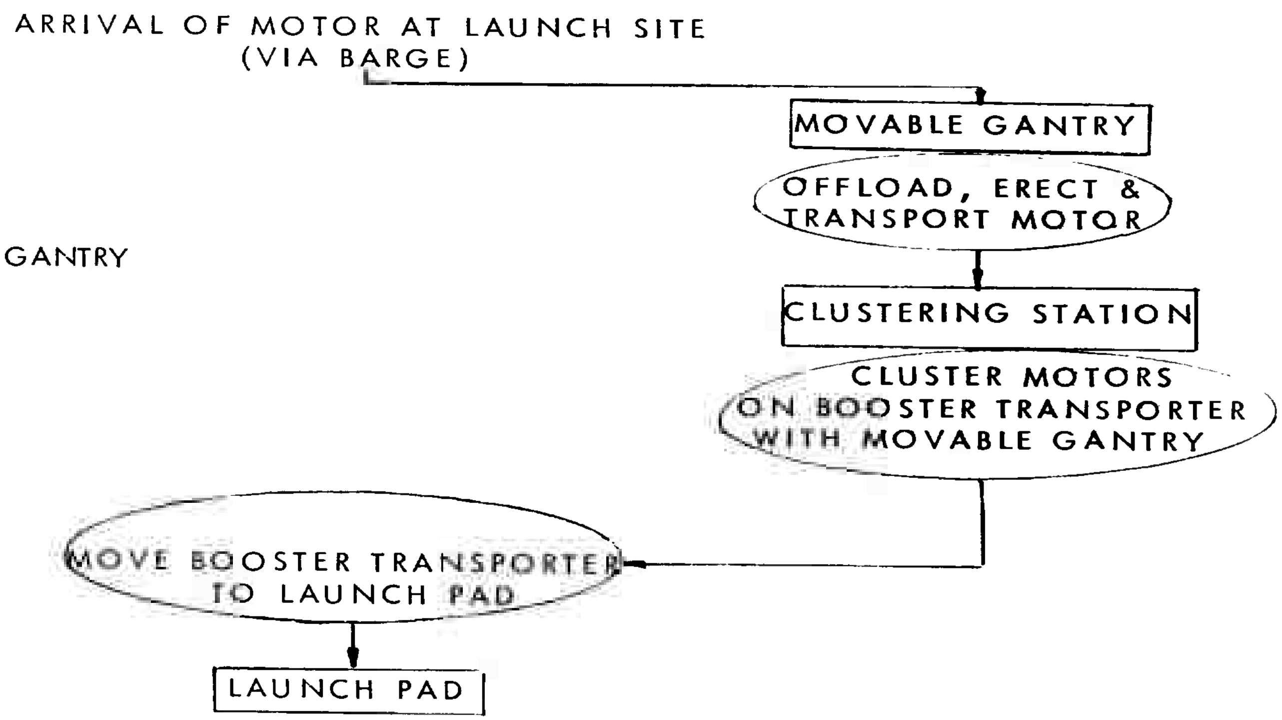


FIGURE 11-11

OFF PAD BOOSTER ASSEMBLY OF 260 - INCH UNITIZED MOTORS
(MOVABLE GANTRY OFFLOADING, TRANSPORT & CLUSTERING ON BOOSTER TRANSPORTER)

SECTION 12

PARAMETRIC EVALUATION OF AGE COST VS. LAUNCH RATE

1. GENERAL

Figure 12-1 and 12-2, pages 12-9 and 12-10 represent the results of a parametric study which contrasts the cost of AGE for the various areas (manufacturing, static test and launch) vs. launch rates. Backup data for these figures are supplied in Tables 12-1 through 12-6, pages 12-3 through 12-8:

> Tables 12-1 through 12-3, pages 12-3 through 12-5 show a compilation of fixed equipment for the various facilities.
>
> Table 12-4, page 12-6 shows quantities of mobile equipment assigned to the various sites (manufacturing, static test and launch) and indicates how the quantities vary with different launch rates.
>
> Table 12-5, page 12-7 is a compilation of the number of fixed facilities containing AGE required for various launch rates.
>
> Table 12-6, page 12-8 shows the cost of the AGE considered on a unit basis.

Explanatory notes affecting the evaluation are supplied in the following paragraph.

It must be emphasized that this evaluation does not give an indication of the variation of over-all site cost with launch rate since facility costs are not included.

2. EXPLANATORY NOTES

1) All calculations are based on the following assumptions.

   a) 120-inch segment - A 624A type vehicle consisting of 2 solid propellant motors. Each motor consists of 4 segments, a top closure, a bottom closure and a nozzle.

b) 156-inch segment - A 624A type vehicle as above.

2) Storage facilities are planned on the basis of a maximum of 500,000 pounds of propellant per facility. It is assumed that this can accommodate (8) 120-inch segments or closures. Segments and closures each contain approximately 60,000 lbs. of propellant. In the case of the 156-inch motors make the following assumptions:

   Weight per Segment = 270,000 lbs.
   Weight per Closure = 136,000 lbs.
   A 10% reduction of total weight due to case and other hardware.
   Each motor consists of 4 segments and 2 closures.
   Total components per storage facility = 2 segments @ 202,000 lbs. of propellant + 1 closure @ 101,000 lbs. of propellant or a total of about 500,000 lbs.

3) All facilities are calculated on the basis of maximum utilization of 96 hours per week. (Two eight hour shifts for six days per week).

4) The number of mobile AGE units spelled out in Table 12-4 page 12-6 was arrived at by engineering judgement.

5) The number of facilities containing AGE, (Table 12-5, page 12-7) was determined on the basis of engineering judgement as to the time required for each operation. Knowing this time and projecting utilization times as spelled out in Note 3) above, it was possible to determine the number of facilities for each launch rate. Detailed estimates were as follows:

   a) X-Raying of 120-inch segments/closure takes 8 hours each - 156-inch segment/closures - 24 hours each.

   b) Packaging for shipping of 120-inch segment/closure takes 4 hours - 156-inch - 8 hours.

6) Facilities 13 and 15 (Table 12-3, page 12-5) will be considered as adding up to one complete storage facility.

7) In the Solid Propellant Motor Assembly Facility (Facility 17), the following rates are assumed:

   120-inch vehicle (two complete motors) - 48 hours
   156-inch vehicle (two complete motors) - 96 hours

FOR DISCISSION REFER TO PAGES 12-1 AND 12-2

TABLE 12-1

COST OF EQUIPMENT IN FIXED FACILITIES AT THE MANUFACTURING SITE

FACILITY NO.	NAME OF FACILITY	EQUIPMENT IN FACILITY	EQUIPMENT COST	
			120 - INCH	156 - INCH
1	Casting Equipment Stripping & Component Inspection Facility	Slings	2,500	3,500
		50 ton overhead crane	65,000	
		150 ton overhead crane		190,000
		Breakover Stand		15,000
		Inspection Platform	7,000	25,000
		Ultrasonic Inspection Equip.	20,000	20,000
		Radiographic Linac	200,000	250,000
		Equipment for Checking physical Dimensions	20,000	30,000
			314,500	533,500
2	Subassembly and Storage Facility Note: This facility is planned on the basis of storage of 500,000 lbs. of propellant. See also Note 2 Page 12-2	8 sets of roller racks	16,000	
		2 sets of roller racks		16,000
		1 set of racks for closures		4,000
		Tie downs	8,000	8,000
		Slings & Block-and-tackle	1,000	2,000
			25,000	30,000
3	Packaging & Shipping Area	50 Ton overhead crane	65,000	
		150 Ton overhead crane		190,000
			65,000	190,000
4	TVC Component Storage Facility	No Fixed Equipment is contemplated	-------	-------
5	TVC Cold Flow Test Area	No Fixed Equipment is contemplated	-------	-------
6	Nozzle/TVC Storage Packing & Shipping	No Fixed Equipment is contemplated	-------	-------

FOR DISCUSSION REFER TO PAGES 12-1 AND 12-2

TABLE 12-2

COST OF EQUIPMENT IN FIXED FACILITIES AT THE STATIC TEST SITE

FACILITY NO.	NAME OF FACILITY	EQUIPMENT IN FACILITY	EQUIPMENT COST	
			120 - INCH	156 - INCH
7	Receiving Motor Storage Facility	Same as Facility # 2 Table 12-1	25,000	30,000
8	Receiving Insp., & Subassembly Facility	Same as Facility # 1 Table 12-1	314,500	533,500
9	Storage & Conditioning Facility	Same as Facility # 2 Table 12-1	25,000	30,000
10	Maintenance Insp., & Subassembly	No Fixed Equipment is Contemplated	-------	-------
11	Vertical Test Bay	50 Ton crane	65,000	
		5 Ton auxiliary hoist	5,000	
		150 Ton crane		190,000
		10 Ton auxiliary hoist		10,000
		Slings	2,500	3,500
		Breakover Stand		15,000
		Environmental Protection	10,000	25,000
		2 Portable work platforms	40,000	60,000
		Motor Support Structure, Source of Pressure, Leak Detector and Equipment for Assembly& Disassembly	50,000	75,000
			172,500	378,500
12	Horizontal Test Bay	Two 140 ton crawler cranes	300,000	
		500 Ton bridge crane		1,000,000
		Environmental Protection	10,000	25,000
		Portable work platform	15,000	15,000
		Motor support structure, Source of Pressure, Leak Detector and Equipment for Assembly &Disassembly.	50,000	75,000
			375,000	1,115,000

FOR DISCUSSION REFER TO PAGES 12-1 AND 12-2

TABLE 12-3

COST OF EQUIPMENT IN FIXED FACILITIES AT THE LAUNCH SITE

FACILITY NO.	NAME OF FACILITY	EQUIPMENT IN FACILITY	EQUIPMENT COST	
			120 - INCH	156 - INCH
13	Receiving Motor Storage Facility	Same as Facility # 2 Table 12-1	25,000	30,000
14	Receiving Insp., & Subassembly Facility	Same as Facility # 1 Table 12-1	314,500	533,500
15	Ready Motor Storage	Same as Facility # 2 Table 12-1	25,000	30,000
16	Maintenance Insp., & Subassembly	No Fixed Equipment is Contemplated	-------	-------
17	Solid Motor Assembly Facility.	50 Ton crane	65,000	
		25 Ton auxiliary crane	25,000	
		150 Ton crane		190,000
	Note: Either facility 17 or 18 can be used, not both.	75 Ton auxiliary crane		75,000
		Hoists & Slings	2,500	3,500
		2 Movable work platforms	40,000	60,000
		2 Solid motor transporters	400,000	1,000,000
		Environmental protection for two motors	20,000	50,000
			552,500	1,378,000
18	Universal Launch Pad Note: Gantry cost is not included as it is not considered AGE	Equipment is identical to Facility # 17 with the exception of the solid motor transporter	152,500	378,500

FOR DISCUSSION REFER TO PAGES 12-1 AND 12-2

TABLE 12-4

PARAMETRIC STUDY OF AGE FOR 120 AND 156 INCH DIAMETER SOLID PROPELLANT MOTORS
(TOTAL QUANTITIES OF EQUIPMENT REQUIRED)

Legend:
M - Manufacturing
S - Static Test Site
L - Launch Site

ITEM NO.	YEARLY LAUNCH RATE / FACILITY	12			24			36			48			60			72			84			96		
		M	S	L	M	S	L	M	S	L	M	S	L	M	S	L	M	S	L	M	S	L	M	S	L
1	SEGMENT DOLLIES	5	4	6	10	4	12	15	4	18	20	4	24	25	4	30	30	4	36	35	4	42	40	4	48
2	NOZZLE/TVC DOLLIES	2	2	2	2	2	4	6	2	6	8	2	8	10	2	10	12	2	12	14	2	14	16	2	16
3	IGNITER MOTOR DOLLY	2	2	2	4	2	4	6	2	6	8	2	8	10	2	10	12	2	12	14	2	14	16	2	16
4	POWER TUG	3	2	4	6	2	8	9	2	12	12	2	16	15	2	20	18	2	24	21	2	28	24	2	28
5	SEGMENT SHIPPING CONTAINER	12			24			36			48			60			72			84			96		
6	CLOSURE SHIPPING CONTAINER	5			10			15			20			25			30			35			40		
7	NOZZLE SHIPPING CONTAINER	3			6			9			12			15			18			21			24		
8	IGNITER SHIPPING CONTAINER	3			6			9			12			15			18			21			24		
9	MOBILE HOISTS 5 & 25 TON	5	5	7	10	15	14	15	5	21	20	5	28	25	5	25	30	5	42	35	5	49	40	5	58
10	SUPPORT CRADLES (156-ONLY)	15	8	15	30	8	30	45	8	45	60	8	60	75	8	75	90	8	90	105	8	105	120	8	120
11	WEATHER PROTECTION	6	6	10	12	6	20	18	6	30	24	6	40	30	6	50	36	6	60	42	6	70	48	6	80

FOR DISCUSSION REFER TO PAGES 12-1 AND 12-2

TABLE 12-5

NUMBER OF FACILITIES VERSUS LAUNCH RATE

Note: Only those facilities which include AGE are listed (Refer to tables 12-1 through 12-3 pages 12-3,4, & 5)

ITEM	YEARLY LAUNCH RATE	12		24		36		48		60		72		84		96	
		120	156	120	156	120	156	120	156	120	156	120	156	120	156	120	156
	MANUFACTURING SITE																
1	Facility No. 1, Refer to Note 5a on page 12-2	1	1	1	2	1	3	1	3	2	4	2	5	2	6	2	6
2	Facility No. 2. Refer to Note 2 on page 12-2	2	4	3	8	5	12	6	16	8	20	9	24	11	28	12	32
3	Facility No. 3. Refer to Note 5b on page 12-2	1	1	1	1	1	1	1	1	1	2	1	2	1	2	1	2
	STATIC TEST SITE																
4	Facilities 7 through 12 except No. 10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	LAUNCH SITE																
5	Facilities No. 13 & 15. Refer to note 2 on page 12-2	2	4	3	8	5	12	6	16	8	20	9	24	11	28	12	32
6	Facility No. 14. Refer to Note 5a on page 12-2	1	1	1	2	1	3	1	3	2	4	2	5	2	6	2	6
7	Facility No. 17. Refer to Note 7 on page 12-2	1	1	1	1	1	1	1	1	1	2	1	2	1	2	1	2
8	Facility No. 18. (Alternate to No. 17)	1	1	1	1	1	1	1	1	1	2	1	2	1	2	1	2

FOR DISCUSSION REFER TO PAGES 12-1 AND 12-2

TABLE 12-6

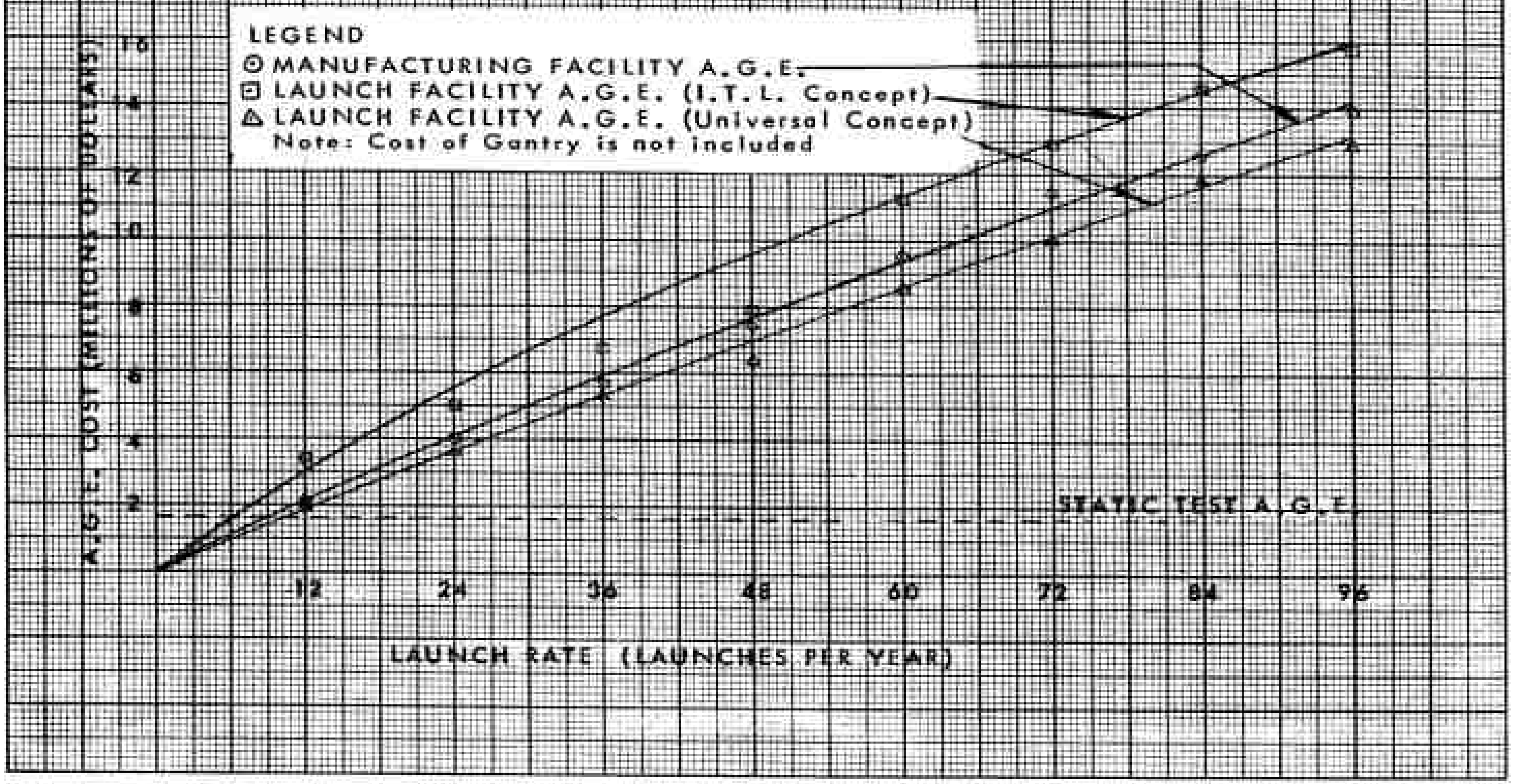
UNIT COST OF A.G.E.

ITEM NO.	DESCRIPTION	UNIT COST -DOLLARS	
		120-INCH	156-INCH
1	SEGMENT DOLLY	20,000	60,000
2	NOZZLE/TVC DOLLY	16,000	40,000
3	IGNITER MOTOR DOLLY	1,000	1,000
4	POWER TUG	15,000	20,000
5	SEGMENT SHIPPING CONTAINER	12,000	20,000
6	CLOSURE SHIPPING CONTAINER	8,000	14,000
7	NOZZLE SHIPPING CONTAINER	6,000	10,000
8	IGNITER SHIPPING CONTAINER	2,000	2,000
9	MOBILE HOIST 5 TON	10,000	
	25 TON		50,000
10	SUPPORT CRADLE		8,000
11	WEATHER PROTECTION	1,000	2,000

FOR DISCUSSION REFER TO PAGES 12-1 AND 12-2

FIGURE 12-1

156 - INCH SEGMENTED MOTOR A.G.E. COST



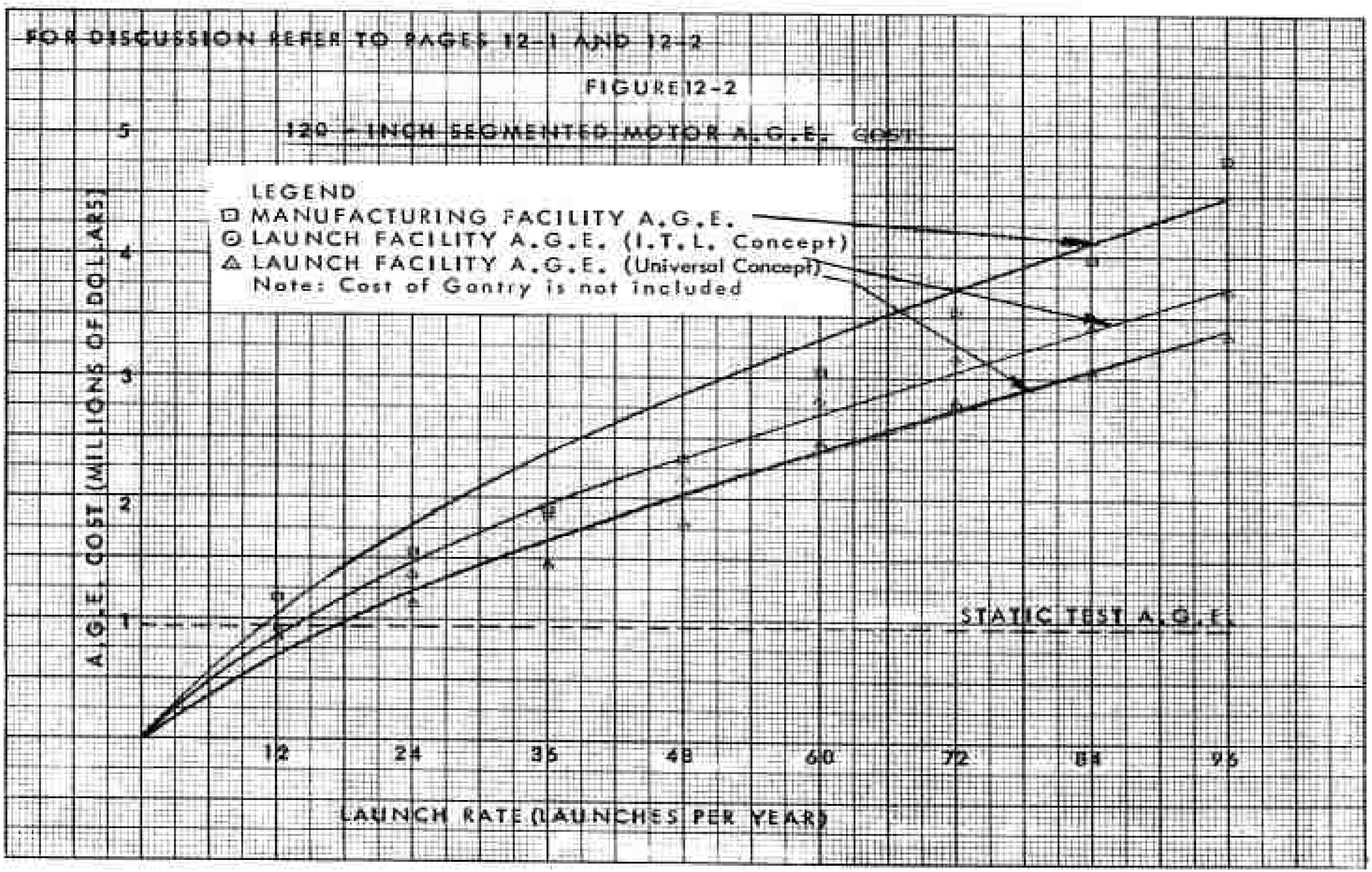


FIGURE 12-2

120 - INCH SEGMENTED MOTOR A.G.E. COST

SECTION 13
CONCLUSIONS AND RECOMMENDATIONS

1. GENERAL

This section will discuss pertinent conclusions and recommendations arising out of the study. Areas which promise profitable returns for future research and development expenditure on the part of the government are pointed out. The following topics are discussed:

1) Categorization of Handling Equipment
2) Application of Existing Military Equipment
3) Heavy Lifting and Transportation Equipment
4) Potentially Large Cost Savings in AGE
5) Comparison of Over-all AGE Costs for the 120 and 156-Inch Segments
6) Transportation
7) Optimization of Transportation Throughout the Continental United States
8) Manufacturing/Static Test of 260-Inch Diameter Unitized Motors
9) Optimization of Ground Systems
10) Facility and AGE studies for Future Vehicle Systems
11) Inspection Equipment
12) Flame Shielding and Deflection
13) On-Site Fabrication of Large Motor Cases and Nozzles

a. Categorization of Handling Equipment.

One of the purposes of the study was to attempt to categorize equipment so that it could be identified for handling motors of specific sizes and weights. In particular it was anticipated that several motor sizes could be identified and the required equipment identified. Once the decision was made to study 120 and 156-inch segmented and 260-inch monolithic motors, it became apparent that categorization beyond those three sizes would be of no further advantage. Equipment for handling 120-inch segments is, in general, readily available, although special equipment is being designed by industry to permit optimization for large scale usage.

Equipment for handling 156-inch segments approaches the upper capacity limit of available lifting and transporting devices. Here again, special purpose equipment will probably be designed for this usage.

For the 260-inch monolithic motor, no applicable equipment is presently available. Therefore, all equipment for handling this motor will have to specially designed and built.

For other motor sizes, extrapolation between the three sizes considered should provide a good idea as to what equipment is feasible for use.

b. Application of Existing Military Equipment.

Military handling and transportation equipment in general is not heavy enough to handle the loads imposed by the 120 and 156-inch solid motor segments. Cranes of adequate capacity for these segments can be found at several shipyards throughout the country, but their availability for the solid propellant motor programs cannot be determined. Auxiliary equipment for handling smaller components such as igniters, rounding rings, etc. can be found in the general listing of the USAF Technical Information File. It is pointed out, however, that this equipment is of very minor significance when compared to the equipment required for handling major components.

c. Modification of Existing Equipment.

For purposes of this study, Modification of Existing Equipment was divided into two sub-categories as follows:

1) Minor Modifications. The addition of auxiliary devices to suit the requirements of solid propellant motor components. An example of this might be the addition of special handling slings to a Ross-type carrier.

2) Major Modifications. The increase in load carrying capacity of an existing design.

Minor Modifications are no problem. Manufacturers will accomodate all reasonable requirements as long as the basic design of the piece of equipment is not affected.

Major Modifications, on the other hand, are tantamount to a redesign. Load carrying devices are generally rated for the maximum load which the manufacturer can guarantee. Any significant increase of this carrying capacity will result in an engineering and design program to determine new configurations. Companies contacted with requests for major modification information responded by saying that they would require funded study programs to come up with the required information.

d. Heavy Lifting and Transportation Equipment.

Lifting devices with capacities up to 32 million pounds are currently within the state-of-the-art. These lifting devices utilize hydraulics or electrically-driven screw jacks. Gantry cranes have been concepted for capacities up to 5000 tons. Crawler-mounted transporters with capacities of approximately 5 million pounds are presently being built. These devices are used to transport completely assembled space vehicles from their assembly facility to the launch facility. A detailed discussion of heavy lifting and transportation equipment can be found in Section 8.

e. Cost Savings in AGE.

Throughout the study, the desirability of pinpointing areas where large cost savings in AGE could conceivably be made, was kept in mind. The following general statements can be made in this connection.

(1) Standardization of Equipment.

1) It is important to standardize equipment for any program so that identical equipment can be used at the Manufacturing Site, Static Test Site and Launch Site.

2) Where programs encompass more than one motor size (i.e., 120 and 156-inch diameter segmented motors) it is highly desirable to design equipment which will handle all sizes.

(2) Multipurpose Equipment.

A detailed study trading off the cost of special equipment vs. that of universal equipment is required before definite recommendations as to the economic advantage of multi-purpose equipment can be made. Such a study must include logistic considerations (i.e., a determination must be made as to the probable programs which would use the multi-purpose equipment together with its utilization rate).

(3) Modular Equipment.

Modular equipment concepts (i.e., equipment concepts which would use small modules of limited utility to be assembled into a variety of complex handling and transportation devices) appear to offer promise for significant reduction in over-all AGE costs. Before forming definite conclusions

in this area, however, further studies are required. These studies should consider the following factors:

1) Cost of single purpose equipment versus cost of equivalent multi-purpose modular equipment.

2) Probable utilization rate of modules (Unless modules are in use a large part of the time, their advantage becomes negated).

3) The degree of idle time to which special purpose equipment would be subjected. (Special purpose equipment which is fully utilized may be more economical than multi-purpose modular equipment performing the same function).

4) Multi-purpose modular equipment will be of significant advantage where modules can be assembled to perform a certain special function and then be reassembled to perform a different special function.

5) Multi-purpose modular equipment design must take into account the effect of existing and planned facilities, i. e., modules and assembled units must be designed with the effects of grades, carrying capabilities of roads and required maneuverability inside of facilities in mind.

(4) Functional and Design Requirments.

Typical of the type of specifications which must be firmed up before development of multipurpose and modular equipment can begin, is the following listing of possible functional and design requirements.

(a) Functional Requirements.

1) Removal of a variety of motor components from barge, railroad flat car or truck trailer.

2) Transporting items listed above to an assembly area.

3) Removal and emplacement of these items onto dollies or platforms.

4) Removal of built-up assemblies to static test or launch sites.

5) Removal, emplacement and/or erection of these assemblies.

To meet these functional requirements the equipment must be able to lift, jack, carry, tow and erect.

(b) Design Requirements to be Firmed Up in a Separate Study.

1) Type of surface over which equipment must move.

2) Distances to be covered, grades to be climbed, velocities at which moved.

3) Physical characteristics of loads to be carried (weights, weight distributions, geometrical configurations).

4) Degree of mobility and steering capability required.

5) Type of propulsion desirable.

(5) Application of Multipurpose AGE to Solid, Liquid and Nuclear Propulsion AGE.

In conjunction with the development of multipurpose equipment, efforts should be made to extend the utility of any equipment developed for solid propellant motors so that it can be used for liquid and nuclear vehicle stages. All these systems (solid, liquid and nuclear) will be used in future space vehicles and the capability of using the same equipment would be of great value to logistic planners.

f. Comparison of Over-all AGE Cost for 120 and 156-Inch Segments.

An evaluation of AGE cost vs. launch rates was made for the 120 and 156-inch segments. This evaluation included AGE at the Manufacturer's Plant, Static Test Site and Launch Site. Facility costs were not included.

It was found that AGE costs for the 156-inch segment will be about three times as high as for the 120-inch segments. Backup data and assumptions may be found in Section 12.

g. Transportation.

Limitations for the various methods of transportation are noted below.

(1) Highway Transportation.

(a) Long Distance.

Diameters up to 13 feet.
Weights up to 100,000 pounds.

(b) Short Distance.

Dependent on route to be taken. Limitations can generally be overcome by modifications of roads and very special transporting devices.

(2) Rail Transportation.

Diameters up to 13 feet, 8 inches.
Weights up to 500,000 pounds.

(3) Air Transportation.

Diameters up to 10 feet.
Weights up to 100,000 pounds.

(4) Water Transportation.

Limited only by off loading facilities and by the transporting vessel. Routes taken should avoid densely populated areas.

The 13 feet, 8 inch rail clearance was determined by a study performed by the Western Region of the Defense Traffic Management Service (DTMS). DOD or NASA for specific routes from the West Coast to Cape Canaveral, Fla. This clearance permits horizontal transport of the 156-inch segment only and both horizontal and vertical transportation of the 120-inch segment.

A second study performed by DTMS compared through rail transport with a combination of rail-barge transport. While the result shows that the combination method costs less, further study is required to determine the cost of trans-loading at intermediate shipping stations. For a further

discussion of transportation, see Section 9.

h. Optimization of Transportation Through the Continental United States.

Future launch sites may well be located in areas other than Cape Canaveral or the Pacific Missile Range. To investigate this problem, the Rocket Research Laboratory requested that the Western region of the Defense Traffic Management Service determine whether a combination of rail transport with barge transport through the inland waterways would offer any advantage. The conclusion was as follows:

Economically, this combination would be cheaper than rail transportation, if it were not for the additional expense of providing transloading facilities at the intermediate shipping stations (the ports of St. Louis, Little Rock, Houston and New Orleans).

Since the economic feasibility of the additional off-loading facilities are a function of their utilization, it may be possible that further effort in this area is required, particularly if areas other than the Atlantic Missile Range are considered as destination points.

Such a transportation study may well point out optimum locations for future solid propellant manufacturing plants other than those contemplated now. It is quite conceivable, for instance, that a plant might be located in the middle west with access to the Mississippi River or to the shores of one of the Great Lakes where inland waterways would permit transportation by barge to the Gulf Coast and from there to Cape Canaveral.

The details of the DTMS study may be found in Section 11.

i. Manufacturing/Static Test of 260-Inch Diameter Unitized Motors.

On the basis of an evaluation of the most promising concepts for manufacturing/static test facilities, it was determined that a completely aboveground facility was superior to either submerged facilities or semi-submerged facilities. The basis upon which the aboveground concept was chosen was: greater reliability, finer control during handling and erection, and lower over-all facility cost.

> NOTE: This result was obtained on the basis of a set of evaluation parameters to which an assumed set of weights was assigned. It is quite conceivable

that different weights assigned to these parameters might result in a different conclusion. A detailed discussion of the concept evaluation method can be found in Section 11.

j. Optimization of Ground Systems.

The prime purpose of this study was to gather available information on existing AGE and to project concepts for areas where no existing equipment or designs could be found. These tasks have been accomplished. It would be ideal if a "best" ground systems approach to each of the solid propellant motor categories could be picked at this time. This, however, is not possible with the available information. Before such a system can be definitized, the implication of the cost of facilities on the over-all ground system would have to be evaluated.

The study of facilities was not within the scope of the study. In a few isolated instances, order of magnitude facility costs were projected in order to obtain a measure of the applicability of AGE concepts. This was done notably in the evaluation of the Manufacturing/Static Test site for the 260-inch monolithic motor.

Before optimum concepts for the over-all ground system can be projected, a number of ground rules for the evaluation have to be established. These ground rules would include, but would not be limited to, the following:

1) The number of different vehicle configurations that would be accommodated.

2) Launch rate of each vehicle considered.

3) Mission (Salvo Launch versus successive launches).

Further discussion of this matter may be found in Section 11. It is AMF's recommendation that additional study work be performed in the above-mentioned areas so that optimization of ground system concepts may be accomplished.

k. Facility and AGE Studies for Future Vehicle Systems.

Facility and AGE studies are required for solid propellant vehicle systems contemplated for the future. The following areas of investigation are presently apparent:

1) Feasibility of Integrated Transfer and Launch techniques for vehicles of Nova and Post Nova class for the purpose of optimizing facilities and AGE for use with high launch densities.

2) Feasibility of offshore launch sites.

Item 1 above is presently being studied by the Martin Marietta Corporation for the NASA. Pending the completion of this study, a determination of whether further effort is required in this area, should be made. Item 2 above has been the subject of several proposal requests from NASA. With the acquisition of the Merritt Island real estate at the Atlantic Missile Range, the necessity for a study of offshore launching techniques was eliminated. It is however, probable that with the increasing size of booster (post Nova) and the associated blast and acoustical hazards, offshore location of launch sites will again become an important consideration.

l. Inspection Equipment.

Inspection techniques presently used for inspection of solid propellant motors include radiography, ultrasonics and visual inspection. As presently used, these methods are quite time consuming. Continuous inspection techniques have not as yet been developed. With the advent of ever-larger motors, these new methods require additional emphasis.

An example is the fluoroscoping method which could replace the relatively slow and cumbersome process of taking X-Ray pictures of each part of the motor. Companies such as Applied Radiation Corp. and Varian Associates are in the process of developing such equipment.

The Perkin Elmer Corp. of Norwalk, Conn. is presently studying the application of infra-red techniques to solid propellant rocket motor inspection problems. The prime purpose of their study was said to be the feasibility of detecting laminar defects (bonding of liner to case and to propellant).

For additional discussion of inspection problems and techniques, refer to Section 10.

m. Flame Shielding and Deflection.

An area which will require considerable research and development effort is that of protecting equipment from the effects of the solid propellant

rocket motor exhaust. It is apparent, for example, that conventional flame deflectors will erode very quickly in view of the fact that solid propellant rocket exhaust contains particles of the propellant . One solution to this problem would be to interpose sufficient distances between the nozzle and any flame impingement. This, however, will add greatly to the cost of the launch facility. To date, this problem has not received any major attention in view of the short impingement time of present systems using solid propellant motors. The large multimotor solid propellant boosters contemplated for the future, however, may require a period of "hold down" on the pad so that proper ignition of all motors is assured prior to launch. The problem of erosion then becomes a major one.

Hughes Aircraft Co. was kind enough to contribute their knowledge of this problem to the study as follows:

In the area of portable, uncooled flame deflectors, phenolic fiberglass compression mold materials, exhibiting excellent erosion resistance to rocket exhausts, can be obtained for $.50 to $1.00 per pound in large quantities. This type of material could be utilized to form the blast resistant surface of portable flame deflectors. Large, interlocking, tile-like sections would be compression molded in matched steel tooling with great uniformity. Existing 25-ton presses could produce sections 48 inches by 48 inches by several inches thick. A series of these tiles could then be mounted on an easily erected steel framework to form a conventional flame deflector. The entire assembly could be so designed as to be easily shipped to remote locations by either truck or rail. If severe erosion of the deflector occurred, all or part of the tiles could easily be replaced. It is the belief of Hughes Aircraft Company that this method of flame deflection is within the present state-of-the-art. However, a brief investigation would be beneficial in determining the optimum plastic material. The success of this approach would be assured by using large presses to produce reasonably sized tile sections.

n. <u>On Site Fabrication of Large Motor Cases and Nozzles.</u>

Studies are presently being conducted by the solid propellant motor industry on handling of the 260-inch monolithic motor. The feasibility of on-site fabrication of motor cases, closures and nozzles would be a distinct advancement of the state-of-the-art. In this area, it should be noted that Hughes Aircraft Company of Culver City, Calif. has recently developed a proprietary method (called the "Keller" process) for high pressure molding of sections of almost unlimited size.

The "Keller" process has the following advantages over previous methods:

1) High pressure curing materials such as graphite, quartz and glass filled phenolics may be used.

2) Only simple tooling, lifting devices, a heat source and other small scale accessory equipment are required. Large hydraulic presses, autoclaves, hydroclaves, wire wrapping and/or deep-sea pressure are not required.

3) From a logistics standpoint, the significance of this method is that the simplicity and availability of the equipment required for the process makes it feasible to fabricate on site. The tooling required can be made in transportable sections. The necessary self-propelled cranes and portable heat sources (Boilers) are readily available.

Details of the "Keller" process will be revealed as soon as proprietary portions have been clarified. It is believed by Hughes, that it would be worthwhile to initiate a manufacturing technique study to develop a 260-inch or larger exit cone by the "Keller" process.

APPENDIX A

SURVEY OF AGE MANUFACTURERS

1. INDEX OF COMPANIES CONTACTED

SURVEY OF

AGE MANUFACTURERS

A.	1 Solid Motor Mfg.	2 Erectors	3 Service Towers	4 Handling Equipment	5 Launch Equipment	6 Test Equipment	7 Hoists, Cranes & Jacks	8 Containers	9 Trailers & Dollies	10 Rail Equipment	11 Radiographic Insp.	12 Ultrasonic Insp.	13 Magnetic Insp.	14 Flourescent/Infrared	15 Optical/Dimensional
ACF Industries		X		X	X					X					
Addelco Corporation											X				
Advance Industrial X-Ray Labs											X				
Aeroaffiliates									X						
Aerojet General Corporation	X	X	X		X	X			X						
Aeronca Manufacturing Company				X											
Ainslie Corporation									X						
Air Cargo Equipment Company				X											
Aircraft Armaments, Incorporated							X								
Aircraft Mechanics, Incorporated							X								
Air Logistic Corporation				X					X						
Alcar Instruments, Incorporated												X			
Allis Chalmers							X		X		X				
Alliance Machine Co.		X					X								
American Astro Systems, Incorporated				X											
American Brake Shoe Company		X		X		X									
American Chain & Cable Company							X								
American Cystoscope Makers, Incorporated														X	
American Hoist & Derrick Company							X								
American Machine & Foundry Company		X	X	X	X	X		X	X						
American Monorail Company							X								
American Optical Company														X	
American Power Jet Company				X					X						
American Rocket Company				X											
American Steel Foundries, Incorporated										X					
Anaconda American Brass Company				X											

SURVEY OF
AGE MANUFACTURERS

A (cont'd) B	1 Solid Motor Mfg.	2 Erectors	3 Service Towers	4 Handling Equipment	5 Launch Equipment	6 Test Equipment	7 Hoists, Cranes & Jacks	8 Containers	9 Trailers & Dollies	10 Rail Equipment	11 Radiographic Insp.	12 Ultrasonic Insp.	13 Magnetic Insp.	14 Flourescent/Infrared	15 Optical/Dimensional
Applied Design Company				X											
Applied Radiation Corporation											X				
Applied Research Laboratories, Incorporated											X				
Arenberg Ultrasonic Laboratory, Inc.												X			
Arnolt Corporation				X											
ARO Equipment Corporation							X								
Associated Company, Incorporated		X	X						X						
Astro Lite Engineering															X
Atlantic Research Corporation	X	X													
Avdel, Incorporated				X											
Avco Corporation				X											
Baker Industrial Trucks							X		X						
Baldwin Lima Hamilton Company		X	X	X	X				X						
Ballymore Company			X				X								
Balteau Electric Corporation											X				
Barnes & Reinecke, Incorporated		X	X	X	X	X			X						
Bar Ray Products, Incorporated											X				
Bausch & Lomb, Incorporated															X
Bearing Inspection, Incorporated															X
Beaver Precision Products							X								
Beech Aircraft Corporation								X	X						
Bendix Corporation												X			
Bethlehem Steel Corporation			X												
Birmingham Manufacturing Company									X						
Black Diamond Trailer Company									X						
Borg Warner Corporation					X				X						
Branson Ultrasonic Corporation												X			

SURVEY OF

AGE MANUFACTURERS

B (cont'd) C	1 Solid Motor Mfg.	2 Erectors	3 Service Towers	4 Handling Equipment	5 Launch Equipment	6 Test Equipment	7 Hoists, Cranes & Jacks	8 Containers	9 Trailers & Dollies	10 Rail Equipment	11 Radiographic Insp.	12 Ultrasonic Insp.	13 Magnetic Insp.	14 Flourescent/Infrared	15 Optical/Dimensional
Breeze Corporations, Incorporated							X								
Brown Engineering Company				X			X								
Brown Knecht-Heinmann Company											X				
Brown & Sharpe Manufacturing Company															X
Buckeye Steel Casting Company										X					
Bucyrus Erie Company							X								
The Budd Company											X				
Burns & Roe , Incorporated					X										
Cadillac Gage Company															X
Caterpillar Tractor Company									X						
Cayne, Albert H. Equipment Company							X								
Chicago Aerial Industries, Incorporated															X
Chisholm Moore Hoist Division							X								
Chromalloy Corporation									X						
Chrysler Corporation		X							X						
Clark Equipment Company							X								
Cleveland Crane & Engineering Company							X								
Cleveland Pneumatic Tool Co.		X		X	X		X		X						
Clyde Iron Works				X			X								
Columbia Research & Development Corp.				X											
Consolidated Diesel Electric Corporation				X											
Consolidated Western Steel				X											
Continental Emsco Company		X	X	X	X				X						
Cosmodyne Corporation									X						
Craig Systems, Incorporated				X					X						
Crane Packing Co.															X
Cryogenic Engineering Company									X						

SURVEY OF AGE MANUFACTURERS

C (cont'd) D, E	1 Solid Motor Mfg.	2 Erectors	3 Service Towers	4 Handling Equipment	5 Launch Equipment	6 Test Equipment	7 Hoists, Cranes & Jacks	8 Containers	9 Trailers & Dollies	10 Rail Equipment	11 Radiographic Insp.	12 Ultrasonic Insp.	13 Magnetic Insp.	14 Flourescent/Infrared	15 Optical/Dimensional
Curtiss Wright Corporation											X	X			
Daystrom, Incorporated											X				
DBM Research Corporation															X
Decker Corporation															X
DeLong Corporation							X								
Designers for Industry													X		
Dorsey Trailers		X							X						
Douglas Aircraft Corporation					X						X				
Delux Metal Products, Incorporated											X				
Delta Corporation											X				
Dressler Electronics									X						
Drott Company							X								
Dynasonics												X			
Dynex Corporation							X								
Eastman Kodak Company											X				X
Easton Car and Construction Company									X						
Eder Instruments Corporation															X
EDO Corporation				X	X										
Elwell Parker Electric Company							X								
Eidal Manufacturing Co.				X					X						
Engis Equipment Company											X	X			X
Equipment Sales Company											X				
Equitable Engineering Company															X
Ex-Cello Corporation															X

SURVEY OF

AGE MANUFACTURERS

F, G	1 Solid Motor Mfg.	2 Erectors	3 Service Towers	4 Handling Equipment	5 Launch Equipment	6 Test Equipment	7 Hoists, Cranes & Jacks	8 Containers	9 Trailers & Dollies	10 Rail Equipment	11 Radiographic Insp.	12 Ultrasonic Insp.	13 Magnetic Insp.	14 Flourescent/Infrared	15 Optical/Dimensional
Fairchild Stratos Corporation		X	X	X	X										
Farrand Optical Company															X
Federal-Mogul-Bower Bearings, Inc.				X											
Field Emission Corporation											X				
Firestone Tire & Rubber Company				X	X										
Flight Refueling, Incorporated							X								
Flight Support Division of General Metals Co.				X											
Food Machinery Corporation		X		X	X				X						
Foster L. W.								X							
Foto-Video Laboratories, Incorporated											X				
Freight Master Division of Halliburton Co.										X					
Fruehauf Trailer Company				X	X				X						
Gardner Denver Company							X								
Garwood Industries, Incorporated							X								
General Analine & Film Corporation											X				
General Dynamics Corporation				X											
General Dynamics/Convair		X	X	X	X				X						
General Electric Co., Ordnance Department				X	X										
General Electric Co., X-Ray Department											X				
General Mills, Incorporated				X											
General Precision, Incorporated															X
Gentry Co.								X							
Glenair, Incorporated				X	X	X									
Globe Hoist Company				X			X								
Goodyear Aircraft Corporation		X	X	X	X				X						

SURVEY OF AGE MANUFACTURERS

H, I, J	1 Solid Motor Mfg.	2 Erectors	3 Service Towers	4 Handling Equipment	5 Launch Equipment	6 Test Equipment	7 Hoists, Cranes & Jacks	8 Containers	9 Trailers & Dollies	10 Rail Equipment	11 Radiographic Insp.	12 Ultrasonic Insp.	13 Magnetic Insp.	14 Flourescent/Infrared	15 Optical/Dimensional
Hammett Mercury-Rex Division											X				
Hardman Tool and Engineering Company		X		X											
Harnischfeger Corporation							X								
Harris, George E. & Company			X	X					X						
Harris, Fredrick R. Incorporated			X	X											
Hercules Power Company	X														
Highland Engineering Company				X											
High Voltage Engineering Company											X				
Hobbs Manufacturing Company									X						
Hoover Electric Company							X								
Houston Fearless Company				X	X				X						
Hughes Aircraft Company											X				
Hughes Trailers									X						
Hyair Corporation				X											
Hydra Cushion, Incorporated										X					
Hydra Power Corporation				X	X										
Industrial Nucleonics											X				X
Industrial Technological Associates				X											
Instrument Development Labs., Inc.															X
ITT Federal Laboratories				X											
Jarrell Ash Company											X				
Johns Manville						X									

SURVEY OF
AGE MANUFACTURERS

K, L	1 Solid Motor Mfg.	2 Erectors	3 Service Towers	4 Handling Equipment	5 Launch Equipment	6 Test Equipment	7 Hoists, Cranes & Jacks	8 Containers	9 Trailers & Dollies	10 Rail Equipment	11 Radiographic Insp.	12 Ultrasonic Insp.	13 Magnetic Insp.	14 Flourescent/Infrared	15 Optical/Dimensional
Kaiser Steel Corporation		X	X	X	X				X						
Kelsey Hayes Company							X								
Kern Instruments, Incorporated															X
Keuffel & Esser Company															X
Keystone Railway Equipment Company										X					
Kidde, Walter & Company									X						
Koehring Company							X								
Kollmorgen Optical Company															X
LaCrosse Trailer Corporation									X						
Lenox Instrument Company															X
LeTourneau, R.G.		X					X								
Le Tourneau Westinghouse		X					X		X						
Ling Temco Vought, Incorporated		X	X	X	X				X						
Link Belt Company		X	X	X					X						
The Lionel Corporation		X	X						X						
Lockheed Aircraft Corporation		X	X	X	X				X						
Lockheed Propulsion Company	X														
Lord Manufacturing Company				X											
Louden Machine Company							X								
The Lovestrand Company				X											
Lowell Wrench Company				X	X										
Lukens Steel		X			X				X						

SURVEY OF
AGE MANUFACTURERS

M, N

	1 Solid Motor Mfg.	2 Erectors	3 Service Towers	4 Handling Equipment	5 Launch Equipment	6 Test Equipment	7 Hoists, Cranes & Jacks	8 Containers	9 Trailers & Dollies	10 Rail Equipment	11 Radiographic Insp.	12 Ultrasonic Insp.	13 Magnetic Insp.	14 Flourescent/Infrared	15 Optical/Dimensional
Magnaflux Corporation												X			X
Manitowoc Company							X								
Manning Maxwell and Moore							X								
Marion Power Shovel Company							X								
Martin Marietta Corporation		X	X		X				X						
MB Electronics											X				
McNeil Machine & Engineering Company							X								
J. E. Menaugh Company															X
George M. Meriwether, Incorporated							X								
Merritt Chapman & Scott							X								
Met-L-Chek Company														X	
M-H Standard Corporation							X								
Milwaukee Crane & Service Company							X								
Minneapolis-Honeywell Regulator Company				X	X										
Mitchell Radiation Products Corporation											X				
Mobile Ariel Towers, Incorporated							X								
Morgan Engineering Company		X					X								
Motorola Inc.						X									
Nashville Bridge Company							X								
National Company, Incorporated															X
National Malleable & Steel Casting Company										X					
New York Shipbuilding Corporation				X											
Neptune Meter Corporation						X									
North American Aviation		X	X	X					X						
North Atlantic Industries, Incorporated															X
Northrop Corporation				X	X										
Northwest Engineering Company							X								

SURVEY OF

AGE MANUFACTURERS

N (cont'd) O, P	1 Solid Motor Mfg.	2 Erectors	3 Service Towers	4 Handling Equipment	5 Launch Equipment	6 Test Equipment	7 Hoists, Cranes & Jacks	8 Containers	9 Trailers & Dollies	10 Rail Equipment	11 Radiographic Insp.	12 Ultrasonic Insp.	13 Magnetic Insp.	14 Flourescent/Infrared	15 Optical/Dimensional
Nuclear Development Corp. of America											X				
Nuclear Equipment & Materials Corporation											X				X
Ohmart Corporation											X				
Optical Gaging, Incorporated															X
Opto Mechanisms, Incorporated															X
Pacific Coast Engineering Company							X								
Pacific Industrial Manufacturing Company							X								
The Parker Hartford Corporation															X
Perkin Elmer Corporation														X	X
Pfaudler Company				X											
Philco Corporation											X				
Philips Electronics Corporation											X				
Photo Mechanisms, Incorporated															X
Piasecki Aircraft Corporation				X					X						
Picker X-Ray Corporation											X				
Pioneer Industries Division Almar York Co.											X				
Pitman Manufacturing Company							X								
Portland Copper & Tank Works				X											
Precision Lapping Company, Incorporated															X
Press Ray Corporation				X											
Pullman Standard										X					

SURVEY OF

AGE MANUFACTURERS

R, S	1 Solid Motor Mfg.	2 Erectors	3 Service Towers	4 Handling Equipment	5 Launch Equipment	6 Test Equipment	7 Hoists, Cranes & Jacks	8 Containers	9 Trailers & Dollies	10 Rail Equipment	11 Radiographic Insp.	12 Ultrasonic Insp.	13 Magnetic Insp.	14 Flourescent/Infrared	15 Optical/Dimensional
Radio Corporation of America											X				
Radionics, Incorporated											X				
Rapids-Standard Company, Incorporated				X											
Ray Proof Corporation											X				
R. E. F. Dynamics Corporation									X						
Regent Jack Manufacturing Company, Inc.							X								
Republic Aviation Corporation		X	X						X		X				X
Republic Steel Corporation				X											
Resitron Laboratories, Incorporated											X				
J. W. Rex Corporation				X											
Richards Wilcox Manufacturing Company							X								
Robbins and Myers, Incorporated							X								
Rogers Brothers Corporation									X						
Rogers Hydraulics Inc.							X								
Rohr Aircraft Corporation				X											
Ronan & Kunzl, Incorporated			X												
Rotiform Corporation											X				
Ryan Aerospace					X										
Ryerson, Joseph T & Son							X								
Safway Steel Products, Incorporated			X				X								
Schaevitz Engineering		X	X												
Semon Bache & Company											X				
Shannon Luminous Materials Corporation													X	X	X
Shawnee Industries, Incorporated			X	X	X				X						
The Sheffield Corporation											X				
Shepard Niles Cranes							X								

SURVEY OF

AGE MANUFACTURERS

S (cont'd) T	1 Solid Motor Mfg.	2 Erectors	3 Service Towers	4 Handling Equipment	5 Launch Equipment	6 Test Equipment	7 Hoists, Cranes & Jacks	8 Containers	9 Trailers & Dollies	10 Rail Equipment	11 Radiographic Insp.	12 Ultrasonic Insp.	13 Magnetic Insp.	14 Flourescent/Infrared	15 Optical/Dimensional
Sheridan Gray, Incorporated									X						
Sicular X-Ray Corporation											X				
The Siegler Corporation		X	X	X	X	X		X							
Silent Hoist & Crane Company							X								
Smith, A. O. Corporation										X					
Solar Aircraft Corporation		X		X					X						
Solartron, Incorporated															X
Southworth Machine Company				X			X								
Space Equipment Company								X							
Sperry Products Company												X	X	X	
Sperry Rand Corporation		X	X	X	X		X								
Standard Car Truck Company										X					
Standard Manufacturing Company				X											
Standard Steel Corporation									X						
L. S. Starret Company															X
State Testing Laboratory											X			X	
St. Johns X-Ray Laboratory											X				
Szemco, Incorporated							X		X		X				
Sun Shipbuilding & Drydock Co.				X											
Talley Corporation							X								
Telecomputing Corporation									X						
Texaco, Incorporated															X
Thew Shovel Company							X								
Thiokol Chemical Corporation	X	X	X	X	X				X						
Thomas Industries, Incorporated														X	
H. I. Thompson Fiber Glass Company				X	X										

SURVEY OF
AGE MANUFACTURERS

T (cont'd) U, V, W	1 Solid Motor Mfg.	2 Erectors	3 Service Towers	4 Handling Equipment	5 Launch Equipment	6 Test Equipment	7 Hoists, Cranes & Jacks	8 Containers	9 Trailers & Dollies	10 Rail Equipment	11 Radiographic Insp.	12 Ultrasonic Insp.	13 Magnetic Insp.	14 Flourescent/Infrared	15 Optical/Dimensional
Thompson Ramo Woolridge , Incorporated					X										
Tinsley Laboratories, Incorporated															X
Torque Controls, Incorporated															X
Tracerlab, Incorporated											X				
Transport Trailers, Incorporated									X						
Trailmobile Trailers									X						
Trio Laboratories, Incorporated															X
Turco Products, Incorporated														X	
Twin Coach Company				X					X						
Ultra Violet Products, Incorporated														X	
Unit Crane & Shovel Corporation		X		X											
United Aircraft Corporation		X		X					X						
United Manufacturing Company				X					X						
United Shoe Machinery Corporation							X								
United States Radium Corporation											X				
United Technology Corporation	X														
Universal Metals Products, Incorporated				X											
United States Steel Corporation		X			X										
Varian Associates											X				
Visioneering Company							X								
Weber Aircraft Corporation				X					X						
Wellman Engineering Company							X								
Wells Industries Corporation							X								

SURVEY OF

AGE MANUFACTURERS

W (cont'd) Y	1 Solid Motor Mfg.	2 Erectors	3 Service Towers	4 Handling Equipment	5 Launch Equipment	6 Test Equipment	7 Hoists, Cranes & Jacks	8 Containers	9 Trailers & Dollies	10 Rail Equipment	11 Radiographic Insp.	12 Ultrasonic Insp.	13 Magnetic Insp.	14 Flourescent/Infrared	15 Optical/Dimensional
Western Gear Corporation							X								
Westinghouse Electric Corporation		X	X	X	X	X			X		X				
White Motor Company							X								
Whiting Company							X								
Wianco Engineering Company															X
Winder Aircraft Corporation		X	X	X	X				X						
Wollensak Optical Company															X
Yale& Towne Manufacturing Company							X								

APPENDIX A

SURVEY OF AGE MANUFACTURERS

2. SUMMARY OF INFORMATION SUPPLIED

NOTE: The mark ** indicates that a trip was made to this Company during the course of this program.

COMPANIES RESPONDING	INFORMATION RECEIVED
ACF Industries	Data on the manufacture of motor cases.
Addelco Corporation	Specifications for 250-400 KV X-Ray Equipment, Catalogue of X-Ray accessories, isotope equipment, radiation protection materials and X-Rays film processing (Engineering Representatives of Bar Ray Products & Westinghouse Corporation).
Advance Industrial X-Ray Labs	No information supplied.
Aeroaffiliates	Nothing applicable.
Aerojet General Corporation **	Studies on the manufacturing, transportation, static test and launch of vehicles using solid boosters.
Aeronca Manufacturing Co.	No information supplied.
Aircraft Armaments, Inc.	Catalogue of hoists ranging from 1/4 to 20 tons. Prices ranges from $400 to $11, 000.
Aircraft Mechanics, Inc.	Nothing applicable.
Air Logistic Corporation	No information supplied.
Alcar Instruments, Inc.	Photos of Ultrasonic inspection equipment.
Allis Chalmers	No information supplied.
American Brake Shoe Co.	Nothing applicable.
American Cystoscope Makers, Inc.	Catalogue of visual inspection devices (Borescopes) capable of inspecting the interior of solid motors.
American Machine & Foundry Co.	Studies of systems utilizing solid motors.
American Monorail Company	Supplied data on low capacity hoists.
American Optical Company	Nothing applicable.
American Steel Foundries, Inc.	Drawings and brochures on rail dollies, cushioning equipment and braking devices.
Anaconda American Brass Co.	Nothing applicable.
Applied Radiation Corporation	Literature on the application of radiographic linear accelerators to the inspection of solid motors. Depending on the degree of flexibility of the radiation beam required, the price ranges between $160, 000 & $200, 000.

** Indicates trip made during the course of this study.

COMPANIES RESPONDING	INFORMATION RECEIVED
Applied Research Labs. Inc.	Literature on Quantometers for X-Ray fluorescence Spectroscopy. Primarily used for control of manufacturing processes.
Arenberg Ultransonic Lab., Inc.	Specifications and costs of ultrasonic inspection equipment.
ARO Equipment Corporation	Nothing applicable.
Associated Company, Inc.	Proposed concepts for transportation, storage and erection of the Titan Missile.
Astro Lite Engineering	Nothing applicable.
Atlantic Research Corporation **	Literature on the Gel-Solid Booster concept.
Avdel, Incorporated	Nothing applicable.
Baker Industrial Trucks	No information supplied.
Baldwin Lima Hamilton Co.	Brochure on AGE capabilities.
Ballymore Company	Brochure and costs of mobile access lifts. Applicable to servicing operations.
Balteau Electric	Specifications and costs of portable X-Ray units in the 140-300 KVA range.
Barnes & Reinecke, Inc.	Concepts for mobile service towers, test stand transporters for solid motors and inspection facilities.
Bar Ray Products, Inc.	Brochures and specifications for X-Ray accessories, isotope equipment and X-Ray film processing units.
Baush & Comb, Inc.	Nothing applicable.
Bearing Inspection, Inc.	Nothing applicable.
Beech Aircraft Corporation	Photograph of Minuteman stage II shipping container and dolly.
Bendix Corporation	No information supplied.
Birmingham Manufacturing Co.	Catalogue of heavy duty trailers with capacities up to 200 tons. (Obtained from AMF catalogue library.)
Black Diamond Trailer Co.	Photographs of trailers and vans.
Branson Ultrasonic Corp.	Brochure and specifications on portable pulsed ultrasonic flax detector.

COMPANIES RESPONDING	INFORMATION RECEIVED
Breeze Corporations, Inc.	Specifications on hand and hydraulically operated winches.
Brown & Sharpe Mfg. Co.	Catalogue and costs of precision measuring devices.
The Buckeye Steel Casting Co.	Data on rail bogies with capacities to 375,000 pounds.
Bucyrus Erie Company	Literature and specifications on large crawler mounted stripping shovels that can be converted to hoisting units with capacities in excess of 1600 tons. Present crawler mounted stripping shovels are equipped with leveling jacks and have a rated speed of .22 mph.
The Budd Company	Brochures on the applications of gamma radiography to small solid propellant rocket motors.
Cadillac Gage Company	Descriptive literature on pneumatic assemblies, regulating systems and precision gauges.
Caterpillar Tractor Company	Their commercial highway trailers and off road hauling units are capable of handling loads of 75 tons.
Chicago Aerial Industries, Inc.	Nothing applicable.
Chisholm Moore Industries, Inc.	Costs and specifications on hand power and electric hoists with capacities between 1/8 and 40 tons.
Chrysler Corporation	No information supplied.
Clark Equipment Company	Brochure on Fork Lift trucks and Ross straddle carriers with capacities to 70,000 pounds.
Cleveland Crane & Engineering Company	Brochure on 100 ton bridge cranes.
Cleveland Pneumatic Tool Co.	Data on erection devices capable of handling 8 million pound motors.
Clyde Iron Works	Data on Derricks and hoists.
Columbia Research & Development Corporation.	Nothing applicable.
Consolidated Diesel Electric Corporation.	Nothing applicable.

COMPANIES RESPONSING	INFORMATION RECEIVED
Continental Emsco Company	Will supply information on proposals they have submitted for handling segments up to 800 tons.
Craig Systems, Incorporated	Brochure on 14,000 pound Class III (rough Terrain) Transporter and shock-mounted shipping containers.
Crane Packing Company	Brochure on optical flats.
Cryogenic Engineering Co.	Nothing applicable.
Curtiss Wright Corporation	Brochures on small X-Ray units (140-260 KVA) and ultrasonic inspection equipment.
Daystrom, Incorporated	No information supplied.
DBM Research Corporation	Nothing applicable.
Decker Corporation	Nothing applicable.
DeLong Corporation **	Drawings, Specs. and costs for pneumatic and hydraulic jacks with capacities up to 1000 tons.
Designers for Industry	Brochure on checkout and guidance equipment.
Dorsey Trailers	Photographs of a transporter and erector for the Redstone Missile and 60 Ton Tank Transporter.
Dressler Electronics	Nothing applicable.
Drott Company	Literature on travel-lifts with capacities to 75,000 pounds. Also pictures of this unit in operation at Aerojet General Corporation and United Technology Corporation.
Dynasonics	Literature on ultrasonic cleaning processes.
Dynex Corporation	Brochure on hydraulic equipment. List of crane manufacturers using their hydraulic equipment for precision hoisting.
Eastman Kodak Company	Literature on the applications of industrial radiography and film processing techniques.

COMPANIES RESPONDING	INFORMATION RECIEVED
Easton Car and Construction Company	Brochure on heavy duty trailers and dollies with capacities to 600 tons.
Eder Instruments Corp.	Brochure and costs of borescopes with lengths up to 27 inches.
Eidal Manufacturing Co.	Data on 300 ton transport trailer and towing vehicles.
Elwell Parker Electric Co.	Nothing applicable.
Engis Equipment Company	Brochure on optical alignment equipment.
Equipment Sales Company	Literature on Zenith pulsed X-Ray units (150 KVA).
Equitable Engineering Co.	Nothing applicable.
Fairchild Stratos Corp.	Nothing applicable.
Farrand Optical Company	Costs and specifications for optical alignment telescope.
Field Emission Corporation	Brochures, specifications and costs for small Flash X-Ray systems. Price of 600 KVP unit is approximately $25,000.
Flight Refueling, Incorporated	No information supplied.
Flight Support Division General Metals Company	Specifications on container and dolly for handling power packages.
Freight Master Division Halliburton Company	Drawings, specifications and costs of rail car cushioning device.
Fruehauf Trailer Company	General capabilities brochure. A drawing of a 300,000 pound trailer concepted by Fruehauf was supplied by Gulf Atlantic Towing Company.
General Analine & Film Corp.	Characterisitc curves for the determination of exposure times for the 65-260 KVA range and for radioisotopes and super voltage X-Ray generatores.
General Dynamics/Convair	No information supplied.

COMPANIES RESPONDING	INFORMATION RECEIVED
General Electric Company X-Ray	Technical data on Resotron 2000KVP unit applicable to radiographic inspection of small solid rocket motors. Cost of unit is approximately $11,0,000.
General Mills, Incorporated	Data sheets on remote handling equipment.
General Precision, Inc.	Information on checkout equipment.
Glenair Incorporated	Data Sheets on flexure pivots used for static testing of motors. (Capacities to 1,500,000 pounds.)
Globe Hoist Company	Brochure on hydraulic lift platforms. They will supply concepts and costs for a 3,000,000 pound hydraulic lift platform.
Harnischfeger Corporation	Literature on cranes with capacities to 100 tons.
George E. Harris & Company	Concepts for engine handling dolly and erection system for light weight vehicles.
Frederic R. Harris, Inc.	Concepts and Cost for a manufacturing/static test facility applicable to 260 inch diameter monolithic motors.
Hercules Powder Company	Preliminary data on the manufacture, handling, transportation, test and launch of filament wound large solid motors.
High Voltage Engineering Co.	Specifications and drawings on radiographic Lineacs between 8 and 15 MEV.
Houston Fearless Company	Photos of handling dollies and trailers with low capacity (16,000 pounds).
Hughes Aircraft Company	Brochure describing applications of radiographic Linac, also information on flame deflectors.
Hydra Cushion, Incorporated	Literature on rail cushioning devices and applied impact tests.
Hydra Power Corporation	Data on small hydraulic components.
Industrial Nucleonics	Literature on Level Detectors and Density Gauges.
Jarrell Ash Company	Literature on industrial radiography and spectroscopy.

COMPANIES RESPONDING	INFORMATION RECEIVED
Johns Manville	Descriptive literature and data sheets on insulation materials.
Kaiser Steel Company	Data and costs on the saturn service tower and other missile test stands and service towers, also concepts of manufacturing/ static test facilities.
Kern Instruments, Inc.	Descriptive literature and costs of missile alignment equipment.
Keuffel & Esser Company	Drawing of a Corescope, used for visual inspection of the interior of rocket motors.
Keystone Railway Equipment Co.	Drawings, costs and descriptive literature on railcar cushioning devices.
Walter Kidde & Company	Descriptive literature on portable pneumatic power systems, fiberglass pressure vessels and automated checkout equipment.
Koehring Company	Literature on truck cranes with capacities to 95 tons and 30 ton capacity dump trucks.
Kollmorgen Optical Company	Brochure on missile alignment equipment.
LaCrosse Trailer Corp.	Specifications and literature on heavy duty trailers with capacities to 75 tons.
LeTourneau Westinghouse	Descriptive literature on mining trucks with capacities to 90 tons.
R. G. LeTourneau, Inc.	Data on hoisting equipment with capacities to 1 million pounds. Information of 5 million pound lifting platforms was also supplied.
Link Belt Company	Capabilities brochure.
Lockheed Propulsion Company **	Studies on manufacturing, transportation, handling, static test and launch of vehicles utilizing solid boosters. Information on transportation survey of 156 inch diameter solid motors.
Lord Manufacturing Co.	Data on shock attenuation pallets, applicable to rail shipment of 120 inch motor segments.
Louden Machine Company	Descriptive literature on monorail cranes and hoists with capacities up to 30,000 pounds.
Lowell Wrench Company	Nothing applicable.
Lukens Steel	Brochure on capabilities of manufacturing dome heads for solid motor cases.

COMPANIES RESPONDING	INFORMATION RECEIVED
Magnaflux Corporation	Brochure and letter on the applicability of magnetic and ultrasonic inspection techniques to case and bond inspection.
Manning Maxwell and Moore	Drawings of various cranes that can be used in support of solid motors. The estimated price of a 2,500 ton gantry crane for use at a NOVA facility is $8,200,000.
Marion Power Shovel Co.	Specificiations and literature on large capacity power shovels and crawler units.
Martin Marietta Corp.	No information supplied.
MB Electronics	Specifications for 150 KVA pulsed X-Ray unit used for measuring high speed phenomenon.
Met-L-Chek Company	Descriptive literature on the uses of penetrent inspection. Primarily applicable to inspection of metal components.
M-H Standard Corporation	Capabilities brochure on industrial conveyor systems.
Milwaukee Crane and Service Co.	Drawings of cranes with capacities up to 750 tons, also supplied data on the undercarriage assembly of the Pad 37 Gantry.
Minneapolis-Honeywell Regulator	Nothing applicable.
Mitchell Radiation Products Corp.	Data on 400 KV X-Ray unit.
Mobile Ariel Towers, Inc.	Pictures showing the applicability of cherry pickers as escape mechanisms.
Morgan Engineering Co.	Concepts for manufacturing/static test facilities for the 260 inch monolithic motor. The Concept's project crane capacities up to 1,600 tons.
Motorola, Inc.	Specifications and literature on test and checkout equipment.
Nashville Bridge Company	General capabilities brochure.
New York Shipbuilding Corp.	Concepts for manufacturing/static test facilities for the 260 inch monolithic motor.
Neptune Meter Corporation	Photos of thrust measuring devices with capacities up to 750,000 pounds and various center of gravity stands.

COMPANIES RESPONDING	INFORMATION RECEIVED
Ohmart Corporation	Literature on thickness and density gauges.
Optical Gaging, Incorporated	Descriptive literature on optical gaging equipment.
Opto Mechanisms, Inc.	Literature on optical instruments.
Pacific Coast Engineering Co.	Data on cranes with capacities up to 40 tons. Their transtainer which loads freight cars can be adapted to loading segments.
Pacific Industrial Manufacturing Company **	Data on hydraulic lifting equipment that can be upscaled to handle multimillion pound loads.
Perkin Elmer Corporation **	Verbal description of infrared inspection techniques for use on solid motors. Work in this area is classified.
Pfaudler Company	Brochure on their capabilities in manufacturing motor case components.
Philips Electronics Corp.	Descriptive literature on the applications of isotope radiography and small X-Ray units (300 KV).
Picker - X- Ray Corp.	Data sheets and costs for image implification system used in flouroscopic inspection.
Pitman Manufacturing Co.	Descriptive literature and photos of aerial personnel lifts.
Press Ray Corporation	Descriptive literature and sketches of handling equipment using pressurized bands to distribute loads.
Pullman Standard	Drawings and specifications for rail car cushioning devices.
Radionics, Incorporated	Suggested that we contact Thiokol Chemical Corporation for necessary information.
Rapids-Standard Co., Inc.	Brochure on conveyors for industrial use.
Ray Proof Corporation	Brochures and specifications on X-Ray Shielding material.
J. W. Rex Corporation	Brochure on their heat treating capabilities.
Robbins and Myers, Inc.	Brochure and costs of powered hoists and lifts with capacities to 20,000 pounds.
Rogers Brothers Corp.	Drawings and specifications on both a 200 and 400 ton highway transporter.

COMPANIES RESPONDING	INFORMATION RECEIVED
Rogers Hydraulics, Inc.	Data sheets, costs and specifications for hydraulic jacks with capacities to 600 tons.
Ronan & Kunzl, Incorporated	Nothing applicable.
Safway Steel Product, Inc.	Brochure on the applications of steel scaffolding.
Schaevitz Engineering	Specification for center of gravity locator and weighing system.
Semon Bache & Company	Nothing applicable.
Shannon Luminous Materials Corporation	Descriptive literature on penetrant inspection.
The Sheffield Corporation	Nothing applicable.
The Siegler Corporation	Supplied photo and cost of transrector capable of erecting motor case 85 inches in diameter by 35 feet long and weighing 80, 000 pounds. Cost of this term is $500, 000.
Silent Hoist & Crane Co.	Specifications on fork lift trucks with capacities up to 60, 000 pounds.
A. O. Smith Corporation	Drawings, specifications and cost of rail cushioning device.
Southworth Machine Co.	Descriptive literature on self-contained lift tables.
Sperry Products Company	Reprints and brochures on the applications of ultrasonic and X-Ray inspection.
Sperry Rand Corp.	Data on checkout equipment applicable to solid motors.
Standard Car Truck Co.	Data on shock attentuation systems for rail-cars.
Standard Manufacturing Co.	Brochure on handling dollies and miscellaneous pieces of AGE.
State Testing Laboratory	Cost of radiographic inspection at their facility is based on time. A cobalt 60 source (10 curies) can penetrate 7 feet of propellant.
L. S. Starret Co.	Data on dimensional checking equipment, ie., gauges.
St. Johns X-Ray Laboratory	Nothing applicable.

COMPANIES RESPONDING	INFORMATION RECEIVED
Szemco, Inc.	Information on low capacity hoists.
Talley Corporation	Specifications and literature on hoists, work platforms and erectors.
Thew Shovel Company	Specifications for their largest rubber tired crane (75 tons) and their largest crawler crane (80 tons).
Thiokol Chemical Corporation **	Studies and descriptive literature on the manufacturing, handling, transportation, static test and launch of space vehicles utilizing solid boosters.
Thomas Industries, Inc.	Nothing applicable.
H. I. Thompson Fiberglass Co.	Descriptive literature on insulating materials.
Thompson Ramo-Woolridge, Inc.	No information supplied.
Tinsley Laboratories, Inc.	Capabilities brochure on optical instrumentation.
Torque Controls, Inc.	Specifications and cost of torque measuring devices.
Trailmobile Trailers	Drawing and preliminary specifications for a 600 ton trailer capable of transporting a complete 120 inch diameter motor.
Transport Trailers, Inc.	Descriptive literature and specifications on transport trailers with capacities to 75 tons.
Turco Products, Inc.	Descriptive literature on penetrant inspection of metal cases.
Ultra Violet Products, Inc.	Brochure on ultra violet inspection techniques.
Unit Crane & Shovel Corp.	Specifications, cost and drawings of an 80 ton truck mounted crane. (Approximate cost $150, 000).
United States Radium Corp.	Nothing applicable.
United Technology Corporation **	Studies and literature on the manufacturing, handling, transportation, static test and launch of space vehicles utilizing solid boosters.

COMPANIES RESPONDING	INFORMATION RECEIVED
Varian Associates **	Drawings, specifications, cost and engineering data on radiographic Linacs up to 25 MEV. (Cost of 25 MEV unit exclusive of cranes and installation is approximately $350, 000.)
Weber Aircraft Corporation	General Capabilities Brochure.
Wellman Engineering Co.	General capabilities brochure including picture of various cranes that they have manufactured.
Western Gear Corporation	Literature and costs on sky climbing devices.
Westinghouse Electric Corp.	Specifications on 150-400 KV X-Ray units.
While Motor Company	Data on 300 ton trailer and 430 HP tractor capable of pulling the trailer.
Whiting Company	Data on cranes with capacities to 400 tons.
Wianco Engineering Company	Literature on weighing and C. G. determination device.
Wollensak Optical Company	Nothing applicable.

APPENDIX B

TRANSPORTATION AND GENERAL INFORMATION SURVEY

1. INDEX OF ORGANIZATIONS CONTACTED

NOTE: All contacts marked * were initially made by Mr. John F. Downing of Lockheed Propulsion Company. Lockheed management was kind enough to turn over their complete letter survey to AMF for inclusion into this study.

The mark ** indicates that a trip was made to this organization during the course of this program.

A, B, C TRANSPORTATION & GENERAL INFORMATION SURVEY	COMMON CARRIERS TRUCK	RAIL	WATER	GENERAL INFORMATION
Aerospace Corporation**				Vehicles/Launch Complexes
Aero Space Lines, Incorporated*				Air Transportation
Air Force Missile Test Center*				Water Transportation
Alabama State Highway Department*				Truck Transportation
American Coastal Lines, Incorporated*			X	
American Commercial Barge Line*			X	
American Trucking Association				Truck Transportation
American Waterway Operators, Inc.				Water Transportation
Arizona Highway Department*				Truck Transportation
Arkansas State Highway Department				Truck Transportation
Ashworth Transfer Company	X			
Association of American Railroads				Rail Transportation
Atchison Topeka & Santa Fe Railroad*		X		
Atlantic Coast Line Railroad*		X		
Bay Cities Transportation			X	
Belyea Company	X			
Bigge Drayage Company	X			
Blue Stack Towing Company*			X	
Bureau of Yards & Docks (U.S. Navy)				Water Transportation
California Department of Motor Vehicles**				Truck Transportation
Canaveral Port Authority				Water Transportation
Chicago Rock Island Railroad*		X		
Colorado State Highway Department				Truck Transportation
Connecticut State Highway Department				Truck Transportation

* Initially contacted by Lockheed Propulsion Company

TRANSPORTATION & GENERAL D, F, G, H, I, J, K INFORMATION SURVEY	COMMON CARRIERS			GENERAL INFORMATION
	TRUCK	RAIL	WATER	
Daniels Towing Service*			X	
Dealers Transit, Incorporated	X			
Debardeleben Marine Corporation*				Harbor Information
Defense Traffic Management Agency				Rail Information
Delaware State Highway Department				Truck Transportation
District of Columbia, Dir. of Highways				Truck Transportation
Federal Barge Lines*			X	
Florida East Coast Railroad*		X		
Florida Inland Navigation District*				Water Transportation
Florida State Road Department				Truck Transportation
Florida Tank Lines*			X	
Galveston, U.S. Army Engineer District*				Transportation
Georgia State Highway Department*				Truck Transportation
Gulf Atlantic Towing Company			X	
Heavy Specialized Carriers Conference				Truck Transportation
Idaho Department of Highways				Truck Transportation
Illinois Central Railroad*		X		
Illinois Department of Public Works				Truck Transportation
Indiana State Highway Commission				Truck Transportation
Iowa State Highway Commission				Truck Transportation
Isbrandtsen Company, Incorporated			X	
Jacksonville, U.S. Army Engineer Dist.*				Transportation
Kansas State Highway Commissions				Truck Transportation
Kentucky, Department of Highways				Truck Transportation

L, M — TRANSPORTATION & GENERAL INFORMATION SURVEY	COMMON CARRIERS			GENERAL INFORMATION
	TRUCK	RAIL	WATER	
Lake Survey, U.S. Army Engineer Dist.				Water Transportation
Leonard Brothers Transfer Company	X			
Arthur N. Lloyd, Incorporated	X			
Lockwood Brothers	X			
Louisiana Department of Highways*				Truck Transportation
Louisville & Nashville Railroad Co.		X		
Los Angeles, U.S. Army Engineer Dist.*				Water Transportation
S.C. Loveland Company*			X	
Lower Mississippi Valley U.S. Army Engineer District				Transportation
Lyon Aircraft Service				Air Transportation
Main State Highway Commission				Truck Transportation
Marine Chartering Company, Inc.			X	
Maryland State Road Commission				Truck Transportation
Massachusetts, Registry of Motor Vehs.				Truck Transportation
Matson Navigation Company			X	
McAllister Towing Company			X	
A.L. Mechling Barge Lines, Inc.*			X	
Michigan State Highway Department				Truck Transportation
Military Sea Transport Service				Water Transportation
Minnesota, Department of Highways				Truck Transportation
Mississippi River Commission				Water Transportation
Mississippi State Highway Department				Truck Transportation
Missouri State Highway Department				Truck Transportation
Montana Highway Commission				Truck Transportation
Moran Towing & Transportation Company			X	

N, O, P, R — TRANSPORTATION & GENERAL INFORMATION SURVEY	COMMON CARRIERS			GENERAL INFORMATION
	TRUCK	RAIL	WATER	
National Aeroanutics & Space Admin.**				Space Vehicle Handling
Nebraska Department of Roads				Truck Transportation
Nevada Department of Highways				Truck Transportation
New Hampshire Dept of Motor Vehicles				Truck Transportation
New Mexico State Highway Department				Truck Transportation
New Orleans Coal & Bisso Towboat Co.*			X	
New Orleans, U.S. Army Engineer Dist.*				Transportation
Newport News Shipbuiliding & Drydock Co.**				Handling
New York, Dept. of Public Works				Truck Transportation
New York Naval Shipyard**				Handling
North Carolina State Highway Commission				Truck Transportation
North Dakota State Highway Department				Truck Transportation
Ohio Department of Highways				Truck Transportation
Oklahoma Department of Public Safety				Truck Transportation
Oregon State Highway Commission				Truck Transportation
Pacific Towboat & Salvage Corporation			X	
Pan American World Airways**				Launch Facility
Panama Canal Company*				Water Transportation
Paxton Trucking Company	X			
Pennsylvania Dept. of Highways				Truck Transportation
Peterbilt Trucking Company	X			
Pope & Talbot, Incorporated			X	
Port of Los Angeles				Water Transportation
Rhode Island, Registry of Motor Vehicles				Truck Transportation

S, T, U TRANSPORTATION & GENERAL INFORMATION SURVEY	COMMON CARRIERS			GENERAL INFORMATION
	TRUCK	RAIL	WATER	
Salt Lake Transfer Company	X			
San Francisco Naval Shipyard**				Handling
Savannah, U.S. Army Engineer District*				Transportation
Seaboard Airline Railroad Company*		X		
Sea Land Services, Incorporated*			X	
Smith Rice Corporation			X	
T. Smith & Sons, Incorporated*				Handling/Stevedoring
South Carolina State Highway Department				Truck Transportation
South Dakota State Highway Commission				Truck Transportation
Southern Pacific Company		X		
Southern Railway System		X		
States Marine Lines			X	
St. Louis-San Francisco Railroad*		X		
Tennessee Department of Highways				Truck Transportation
Texas & Pacific Railroad Company		X		
Texas Highway Department*				Truck Transportation
G. W. Thomas Drayage & Rigging			X	
Todd Shipyards, Incorporated				Barge Concepts
Transportation & Research Command, U.S. Army**				Transportation
Truck-Trailer Manufacturers Assoc., Inc.				Truck Transportation
Union Barge Lines*			X	
Union Pacific Railroad		X		
United States Air Force**				Space Vehicle Handling
United States Coast & Geodetic Survey				Maps
United States Coast Guard				Water Transportation
United States Government Printing Office				Transportation
U.S.A.C. Transport	X			
Utah, State Road Commission				Truck Transportation

V, W — TRANSPORTATION & GENERAL INFORMATION SURVEY	COMMON CARRIERS			GENERAL INFORMATION
	TRUCK	RAIL	WATER	
Vermont Motor Vehicle Department				Truck Transportation
Virginia Department of Highways				Truck Transportation
Washington Department of Highways				Truck Transportation
West Virginia Department of Highways				Truck Transportation
Wisconsin State Highway Department				Truck Transportation
Wyoming Highway Department				Truck Transportation

APPENDIX B

TRANSPORTATION AND GENERAL INFORMATION SURVEY

2. SUMMARY OF INFORMATION SUPPLIED

ORGANIZATION RESPONDING	INFORMATION SUPPLIED
Aerospace Corporation**	Studies applicable to the handling, static test and launch of vehicles utilizing solid boosters.
Aero Spacelines, Incorporated*	Literature on the modification of existing aircraft to carry packages of unusual size and weight.
Air Force Missile Test Center*	No information supplied.
American Coastal Lines, Inc. *	There is no equipment in the State of Florida capable of lifting 100 tons.
American Commercial Barge Line*	Supplied rates (not including loading) and transit times for barging between Houston, Texas and New Orleans, Louisiana or Huntsville, Alabama.
American Waterway Operators, Incorporated	Map of all navigable waterways in the United States and a brochure on waterway operations.
Ashworth Transfer Company	Their equipment can handle segments up to 250,000 pounds.
Association of American Railroads	Supplied information on the classification of explosives for all rail transportation, the manufacturers of cushioning devices for rail cars and a circular listing all heavy duty flat cars in service.
Atchison Topeka & Sante Fe Railroad*	No information supplied.
Atlantic Coast Line Railroad*	Clearance Diameter on their line is 13'-6", anything greater than 13'-2" must travel daylight hours only.

* Initially contacted by Lockhead Propulsion Company

** Indicates trip made during the course of this study.

ORGANIZATION RESPONDING	INFORMATION SUPPLIED
Bay Cities Transportation	Cost data for barging individual segments from San Francisco dockside to an explosive anchorage. As of 1964 costs are as follows: 125 foot barge, $75 per day; 200 foot barge, $175 per day. Barges are valued at $75,000 and $150,000, respectively. Tug costs are $20/hour standby, $30/hour operating, and $35/hour overtime.
Belyea Company	The cost of moving a 1,000,000 pound, 30 foot diameter load from the Aerojet General Corporation plant to a dock would be as follows: on loading $10,000; off loading $25,000; equipment cost $90,000 and transportation cost $9,000.
Bigge Drayage Company	Cost data for transporting 120 inch diameter segments from the San Francisco area to Edwards AFB. Also obtained were costs of equipment and handling and drawings of the Transport Trailers.
Bureau of Yards and Docks (U. S. Navy)**	Information on high capacity cranes.
Canaveral Port Authority	Tariff applicable to Port Canaveral. The Port has a 400 foot long marginal wharf with 33 feet water depth along side.
Chicago Rock Island Railroad*	Solid motors would probably fall in uniform freight classification no. 6. The costs from Beaumont, Calif. (Lockheed Facility) to Melbourne, Fla., would be $6.26 per 100 pounds. Diameters of 14 feet can only be handled between Tucumcari, N. M. and Oklahoma City. This route is restricted to a gross weight of 250,000 pounds.

ORGANIZATIONS RESPONDING	INFORMATION SUPPLIED
Daniels Towing Service*	Depth of inland waterway, Jacksonville to Fort Pierce is 10 feet. Cranes in Gibbs Shipyard at Jacksonville could probably handle 150 tons. 500 ton barges rent for $40 per day and tugs of 300-400 h. p. rent for approximately $275 per day.
Debardeleben Marine Corp. *	They are presently constructing a barge docking facility at Cape Canaveral. No lifting equipment of 150 ton capacity is being planned for this facility.
Defense Traffic Management Agency	DTMA has recently supplied a study on rail transportation from the four major solid motor manufacturers to Edwards AFB, Vandenberg AFB and Cape Canaveral. They have cleared a segment 13'-8" in diameter, 25 feet long and weighing 340,000 pounds. This clearance has been extended only to DOD/NASA, and is predicated on the use of rail car number 16153 which has a gross weight capacity of 502,000 pounds. Only one car of this type exists. Also supplied by DTMA was a study done for UTC on the transfer of segments weighing up to 800,000 pounds from the UTC manufacturing facility to a nearby port.
Federal Barge Lines*	Costs of barge transportation between Houston or New Orleans and Huntsville. Using a barge with dimensions of 195' x 35' and an 8'-6" draft, 1200 tons could be accommodated.
Florida East Coast Railroad*	The maximum diameter that can be shipped between Jacksonville and Benson Junction is 13'-6", under severe restrictions 14' could be handled between Benson Junction, Fla. and Cocoa Rockledge, Fla.
Florida Inland Navigation District*	Names of towing companies on the Florida Coast.

ORGANIZATIONS RESPONDING	INFORMATION SUPPLIED
Galveston, U. S. Army Engineer District*	Suggested contacting Defense Traffic Management Agency.
Gulf Atlantic Towing Company	Suggest use of Army Explosive facility at St. Marys, Georgia, if loading is not allowed at Jacksonville Harbor. Intracoastal Waterway depth Jacksonville to Cape Canaveral cutoff is 9 feet. Depth into Cape is 7 feet. Cost Data:

Tugs	Cost per Day	Barges	Cost per Day
500 hp	$ 500	500 ton Intracoastal	$100
650 hp	$ 600	3000 ton coaswise	$250
1000 hp	$ 900	Deck Barge	
1250 hp	$1000		

Also supplied was a drawing of their barge terminal in Jacksonville and a drawing of a 150 ton trailer supplied by Fruehauf Trailer Company (approximate cost of trailer is $32,000).

ORGANIZATIONS RESPONDING	INFORMATION SUPPLIED
Heavy Specialized Carriers Conference	Listing of heavy specialized carriers.
Isbrandtsen Company, Incorporated	Cost information cannot be generated without definitive breakdown of cargo and shipping schedules.
Jacksonville, U. S. Army Engineer District*	Brochure on the conditions of channels of the Intracoastal Waterway (Fernandia to Key West) and Okeechobee Waterway. The Canaveral harbor barge canal is 8' deep by 100' wide.
Lake Survey, U. S. Army Engineer District	Catalogue of available navigation charts applicable to the Great Lakes.
Leonard Brothers Transfer Co.	It may be possible to transport 500 ton loads for short distances via highway.

ORGANIZATIONS RESPONDING	INFORMATION SUPPLIED
Arthur N. Lloyd, Incorporated	Cost data on shipment from Cocoa Rockledge Rail head to Cape Canaveral. Also supplied sketches of transport trailers.
Louisville & Nashville Railroad Co. *	Maximum clearance New Orleans, La.to Chattahoochee, Fla 13'-6". Also supplied estimated costs of changing clearances to 14' (approximate estimate $2.8 million).
Lower Mississippi Valley, U. S. Army Engineer Division	Navigation conditions for the Mississippi River 1962, General brochure on Mississippi River navigation and various maps.
S. C. Loveland Company*	Cost of shipping a single 150 ton segment (excluding loading and unloading) to Cape Canaveral are as follows: From — Cost Jacksonville — $ 3,500 New Orleans — $11,750 Houston — $16,900 Houston and New Orleans have capabilities of handling 150 tons. Also supplied picture of barge to be used.
Lyon Aircraft Service	No information supplied.
Marine Chartering Company, Inc.	Suggest manufacturing motor on barges built in Slipways. Costs of building barges are $300 per ton between 1000 and 5000 tons.
Matson Navigation Company	Do not provide service from Los Angeles to Gulf Ports or East Coast.
A. L. Mechling Barge Lines, Inc. *	Do not have certificate to transport solid motors.
Military Sea Transport Service	Can only transport Defense Department materials.

ORGANIZATIONS RESPONDING	INFORMATION SUPPLIED
Mississippi River Commission	Brochures and maps dealing with navigation on the Mississippi River system.
Moran Towing & Transportation Company	Costs of transportation would have to be based on quantities of items shipped, schedules and number of years equipment is in operation.
National Aeronautics & Space Administration**	Studies applicable to the handling, static test, and launch of vehicles utilizing solid boosters.
New Orleans, U. S. Army Engineer District*	Gulf intracoastal waterway has a minimum depth of 12 feet and width of 125 feet. The controlling dimension is at the Vermilion Lock (New Orleans) where the depth is 11.3 feet and width is 56 feet.
Newport News Shipbuilding & Drydock Company**	Photos and information on handling large packages.
New York Naval Shipyard**	Drawings of cranes that have been used at this facility.
Pan American World Airways**	Details of facilities at the Cape Canaveral Missile Test Center.
Panama Canal Company*	Detailed information on the items to be shipped is required prior to obtaining clearance for use of the Panama Canal.
Paxton Trucking Company	Costs of transporting 10 feet diameter segments from Lockheed Propulsion Company to Vandenberg AFB.
Pope & Talbot, Incorporated	Shipboard tariffs do not include solid rocket motors. They are therefore unable to transport on board ship.
Port of Los Angeles	It is permissible to ship Class B explosive over various docks to the Los Angeles Harbor.

ORGANIZATIONS RESPONDING	INFORMATION SUPPLIED
San Francisco Naval Shipyard**	Drawing and descriptive literature on the 500 ton bridge crane located at the Shipyard.
Savannah, U. S. Army Engineer District*	Suggested use of Kings Bay Ammunition Depot at St. Marys, Ga., as a possible loading site.
Seaboard Airline Railroad Co. *	14 feet segment can be handled from Chattahoochee, Fla. to Jacksonville, Fla. under severe restrictions.
Smith Rice Corporation	Charge for 60 ton crane at explosive anchorage is approximately $400 per day.
Southern Pacific Company	Clearance information from California to Cape Canaveral. From Nimbus, Calif. to Cocoa Rockledge, Fla. the cost is $637 per hundred pounds. Also supplied were costs for armed guards.
Southern Railway System	Maximum clearance on this line is 12'-9". A cost of approximately 2.7 million dollars would be incurred in changing clearance to 14 feet.
State Highway Departments	All states supplied information on their restrictions to overdimensional and overweight highway transportation.
States Marine Lines	Latest cost of shipping from San Francisco to Cape by Steamship is $9.54 per 100 pounds.
Texas & Pacific Railroad Co.	The largest diameter that can be handled between El Paso, Texas and Schreveport, La. is 14'-4". Transportation would have to be restricted to daylight hours. Also supplied was a clearance diagram for their line.
G. W. Thomas Drayage & Rigging	The estimated cost of transporting segments with diameters of 13 feet and weighing between 65,000 and 125,000 pounds from Coyote, California to the Port of Redwood City (Including loading and unloading) is approximately $430.

ORGANIZATIONS RESPONDING	INFORMATION SUPPLIED
Todd Shipyards, Incorporated	Supplied conceptual effort on manufacturing -Static Test of large solid motors.
Transportation & Research Command, U. S. Army**	Drawings and photos of amphibious craft with capacities to 300 tons and landing craft retrievers with capacities to 100 tons.
Truck-Trailer Manufacturers Association, Incorporated	Chart of state size and weight restrictions for highway transport.
Union Pacific Railroad	Clearance between Corrine, Utah and Cocoa Rockeledge, Fla. is 13'-8". Over certain portions of the track only cars similar to D&H 16153 can be used. Rate is 527¢ per hundred pounds to Cocoa Rockledge. Alternate routes via California can increase cost as much as 50%.
United States Air Force**	Space Systems Division, El Segundo, Calif. and 6555 Test Wing, BSD, Cape Canaveral, Fla. supplied information and studies relating to space vehicle systems utilizing solid boosters.
United States Coast & Geodetic Survey (Maps)	Catalogue of available maps.
United States Government Printing Office	Catalog of literature available on transportation.
U. S. A. C. Transport	Costs and routings for shipment of 10 foot to 13 foot diameter segments weighing 65,000 pounds from California to Florida vary between $10,000 and $13,000.

APPENDIX C

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430 p. incl illus., tables.

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1) An extensive survey of government and industry to compile available information and advanced thinking in areas of equipment, transportation and handling techniques as applied to large solid propellant rocket motors.
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6) A determination of potential problem areas in Aerospace Ground Equipment development and areas where future R and D funding could profitably be applied.

The study intended to establish preliminary criteria for guiding subsequent Aerospace Ground Equipment developers likely to be engaged by the military in specific weapon system programs.

1. Ground Support Equipment
2. Solid Propellant Rocket Motors

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Task No. 817201
II. Contarct No. AF 04(611)-8187
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The study intended to establish preliminary criteria for guiding subsequent Aerospace Ground Equipment developers likely to be engaged by the military in specific weapon system programs.

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2. Solid Propellant Rocket Motors

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Headquarters Rocket Propulsion Labratory, Research and Technology Division AFSC, Edwards, California. Technical Documentary Report No. RDT-TDR-63-1025. A STUDY OF AEROSPACE GROUND EQUIPMENT REQUIREMENTS FOR LARGE SOLID PROPELLANT ROCKET MOTORS. Final Report, June 1963, Volume I
430 p. incl illus., tables.

Unclassified Report

This report descrides the investigations accomplished during this study of the Aerospace Ground Equipment Requirements For Large Solid Propellant Rocket Motors.
The work performed during the study encompassed the following:

1) An extensive survey of government and industry to compile available information and advanced thinking in areas of equipment, transportation and handling techniques as applied to large solid propellant rocket motors.
2) A review of existing studies and an abstracting of the most promising of available documents for use as background material for interested parties.
3) A compilation and evaluation of concepts for handling, transportation, static test, and assembly-to-upper-stages-of-vehicles of large solid propellant rocket motors.
4) Establishment of Detailed Handling Procedures for solid propellant rocket motor components at the manufacturing site, at the static test site and at the launch site.
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